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Aeronautical Engineering REVIEW

March, 1955

How the Holley Turbine Control helps jet pilots concentrate on FIGHTING, not flying

Nearly every foot of altitude, gained or lost, nearly every minute change in atmospheric conditions alters the amount of fuel flow needed by today's jet engine. Literally hundreds of mathematical problems must be solved every minute a jet is in the air. It would be impossible for any pilot to solve all these problems and still have time to concentrate on fighting. So the Holley Turbine Control was developed to solve them for him AUTOMATICALLY.

Holley's research department played an important role in the development of this mechanical wizard. But producing Holley Turbine Controls requires special skills, too. Working to tolerances of as little as plus or minus 25 millionths of an inch, the Holley manufacturing division turns out turbine controls for thousands of today's jet aircraft.

Holley's highly-trained research, engineering and manufacturing staff can support your program of producing better products for the aviation industry, either your design or ours.

Leader in the design, development, and manufacture of aviation fuel metering devices.

HOLLEY Carburetor Co.

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Aeronautical Engineering Review

Vol. 14—No. 3 March, 1955

CONTENTS

Honors Night Dinner Address ..... *Roger Lewis* 32

Test Cell Augmenter Design ..... *Richard D. Lemmerman and Harold J. Lockwood* 37

Synthetic Fabric-Acrylic Resin Impregnates for Aircraft Canopy Edge Attachments ..... *W. G. Carson and E. N. Robertson* 44

Flight-Test Instrumentation—Engineering and Instruments ..... *Gilbert L. Roth* 50

Taming Titanium ..... *Dave Adams* 59

Allocation of Fuel and Cargo for Maximum Ton-Miles ..... *A. N. Petroff* 64

IAS News Notes 17
IAS News 19
Editorial 30
Special IAS Publications 49
Aeronautical Reviews 99
Sherman M. Fairchild Publication Fund Papers 126
Books 129
IAS Preprints 133
Personnel Opportunities 139
Index to Advertisers 149
New Products and Product Literature 151

Cover—The U.S. Air Force's new all-weather supersonic interceptor, the YF-102A, is shown taking off on a test hop at Edwards AFB, Calif. This delta-wing aircraft, which was built by the Convair-San Diego Division of General Dynamics Corporation, flew supersonically in level flight its second time in the air.

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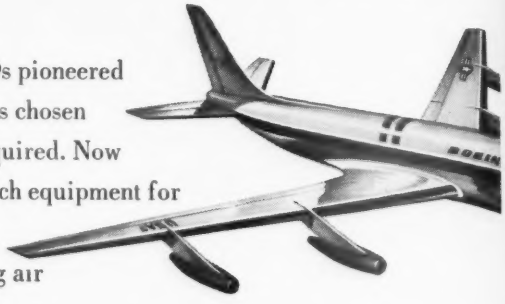

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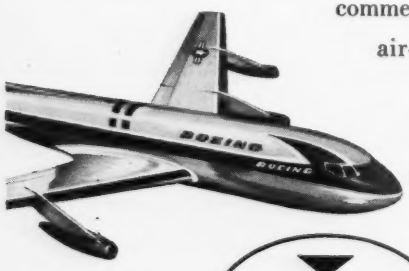

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I.A.S. News Notes

March 1955

IAS COSPONSORING ELECTRONICS CONFERENCES

The Institute is cooperating with the IRE on the program for the National Conference on Aeronautical Electronics, to be held May 9-11 at the Dayton Biltmore Hotel, Dayton, Ohio. The National Telemetering Conference, co-sponsored by IRE, AIEE, ISA, and IAS, is scheduled for May 18-20 at the Hotel Morrison, Chicago, Illinois. Details of the programs will be announced in the April issue of the REVIEW.

* * * * * * *

GENERAL KELSEY TO SPEAK

Brig. Gen. Benjamin S. Kelsey, USAF, FIAS, will speak on "The First and Last Thousand Feet" at the annual luncheon of the Institute of Radio Engineers' Professional Group on Aeronautical and Navigational Electronics. The luncheon will be held on March 22 at the Waldorf-Astoria, New York.

* * * * * *

SAFETY CONVENTION

The Twenty-Fifth Annual Safety Convention and Exposition will be held in New York April 11-15 at the Hotel Statler. Safety aspects of cargo handling and the hazards of aircraft refueling will be discussed in the aviation session. Advance copies of the full program may be obtained from the Greater New York Safety Council, Inc., 60 East 42nd Street, New York 17, New York.

* * * * * *

NATIONAL MEETINGS CALENDAR

March 11	National Flight Propulsion Meeting (Restricted), Hotel Carter, Cleveland, Ohio.
June 21-24	Fifth International Aeronautical Conference, IAS Building, 7660 Beverly Blvd., Los Angeles, California.
Aug. 8-10	Turbine Powered Air Transportation Meeting, Seattle, Washington

* * * * * *

CALENDAR OF SECTION MEETINGS

Mar. 9-- Niagara Frontier Section: Park Lane Hotel, Buffalo. Social Hour, 6:30 p.m.; Dinner Meeting, 7:30 p.m. "Air Power: A Scientific Evolution" by Lt. Gen. W. E. Kepner, USAF (Ret.), Executive Vice President, Bell Aircraft Corporation.

Mar. 9-- Washington Section: Occidental Restaurant. Social Hour, 6:00 p.m. Dinner, 6:45 p.m.; Meeting, 8:00 p.m. "New NACA Wind Tunnels:

CALENDAR OF SECTION MEETINGS (CON'T.)

Tools for Developing Supersonic Air Power" by speakers from Ames, Langley, and Lewis Laboratories. Dr. Hugh L. Dryden, Chairman.

Mar. 10--Atlanta Section: Dinner Meeting, 7:00 p.m. "Army Mobility" by Brig. Gen. William C. Westmoreland.

Mar. 10--Baltimore Section: Maryland Hall, Johns Hopkins University. Meeting, 8:30 p.m. "Latest Developments in Aircraft Carrier Operations" by Lt. Cmdr. James L. Holbrook, USN.

Mar. 10--Los Angeles Section: Long Beach, 7:00 a.m. Aircraft Carrier Field Trip aboard U.S.S. "Hancock."

Mar. 10--St. Louis Section: Specialist Meeting, 8:00 p.m. "Testing Rocket-Powered Models" by an NACA aeronautical research scientist.

Mar. 10--Seattle Section: Chamber of Commerce Building. Annual Banquet of the Puget Sound Engineering Council, 6:30 p.m. "Aircraft Engineering" by George Martin, Chief Engineer, Boeing Airplane Co. "The Boeing 707" by Maynard L. Pennell, Chief Project Engineer. William M. Allen, Toastmaster.

Mar. 17--Los Angeles Section: IAS Building. Social Hour, 6:00 p.m.; Dinner, 7:00 p.m.; Meeting, 8:15 p.m. Talk by Robert E. Gross, President, Lockheed Aircraft Corp., and President, IAS.

Mar. 21--Los Angeles Section: IAS Building. Confidential Specialist Meeting, 8:00 p.m. "Some Considerations Affecting the Performance of Fuselage Side Inlets" by Emmet A. Mossman, Aeronautical Research Scientist, Ames Aeronautical Laboratory, NACA.

Mar. 23--St. Louis Section: Engineers Club of St. Louis. Meeting, 8:00 p.m. Panel Discussion on "Structural Fatigue Problems in Aircraft Design." Conducted jointly with the American Helicopter Society.

Mar. 24--Dayton Section: Cordell's Supper Club, Fairborn. Social Hour, 6:30 p.m.; Dinner, 7:00 p.m.; Technical Discussion, 8:00 p.m. "Packaged Power" by J. J. O'Neill, Assistant General Manager, Explosives Division, Olin Mathieson Chemical Corporation.

Mar. 31--Wichita Section: "Toward New Horizons with Rocket Propulsion" by William Bollay, President, Aerophysics Development Corp.

Apr. 13--Niagara Frontier Section: Crosby-Brounshidle Post. Meeting, 8:00 p.m. "Techniques of Model Testing in Free Flight" by Joseph A. Shortal, Chief of the Pilotless Aircraft Research Division, Langley Aeronautical Laboratory, NACA.

Apr. 21--Los Angeles Section: IAS Building. Social Hour, 6:00 p.m.; Dinner, 7:00 p.m.; Meeting, 8:15 p.m. Lecture on Guided Missiles by Dr. R. E. Gibson, Director, Applied Physics Laboratory, The Johns Hopkins University.

Apr. 23--Los Angeles Section: IAS Building. Annual Spring Dance, 9:15 p.m.

* * * * * * *

IAS News

A Record of People and Events of Interest to Institute Members

Annual Business Meeting of the Institute

Reports of President, Treasurer, and Director

THE TWENTY-THIRD ANNUAL MEETING of the members of the Institute was held at the Hotel Sheraton-Astor, New York, on January 26, 1955. P. R. Bassett, Chairman of the Executive Committee, presided.

Charles H. Colvin, Teller, reported that he had received and counted 1,223 valid proxies for voting at the Annual Meeting—a quorum of the voting membership. T. P. Wright, Chairman of the Nominating Committee, placed in nomination the following members for election to vacancies on the Council: Robert E. Gross, J. L. Atwood, Charles H. Colvin, Roger W. Kahn, T. Claude Ryan, E. R. Sharp, and Edward C. Wells, for a term of 1 year each; W. A. M. Burden, G. F. Chapline, J. H. Doolittle, C. J. McCarthy, and E. A. Sperry, Jr., for a term of 3 years each; and the following area councilors for a term of 1 year each: Eastern Area—Louis Fahnestock and William C. Fortune; Central Area—Eugene J. Manganiello and John H. Meyer; Western Area—Harold Luskin and John R. MacGregor. On motion duly made, seconded, and carried, they were unanimously elected. The following were nominated and elected in like manner to serve on the Nominating Committee for 1955: P. R. Bassett, Chairman; W. E. Beall; W. A. M. Burden; F. W. Caldwell; L. de Florez; J. Lederer; A. E. Raymond; and D. Sayre.

The Annual Reports of the President, Treasurer, and Director were read and approved. (See the following pages for the complete reports.)

The Secretary presented a list of honors conferred by the Institute in 1954 as follows:

The Thurman H. Bane Award to Helmut G. Heinrich, Aeronautical Research Engineer, Equipment Laboratory, WADC; The Octave Chanute Award to George E. Cooper, Chief Aeronautical Research Pilot, Ames Aeronautical Laboratory, NACA; The John Jeffries Award to James P. Henry, Chief, Acceleration Unit, Aero Medical Laboratory, Wright-Patterson AFB; The Robert M. Losey Award to Hermann B. Wobus, Meteorologist, Project AROWA (Applied Research Operational Weather Analysis), Bureau of Aeronautics; The Sylvanus Albert Reed Award to Clark B. Millikan, Director, Guggenheim Aeronautical Laboratory and Southern California Wind Tunnel, C.I.T.; The Lawrence Sperry Award to A. Scott Crossfield, High Speed Flight Station, NACA; and the Wright Brothers Lecturer, Bo Lundberg, who spoke on "The Fatigue Life of Airplane Structures."

Honorary Fellowships in the Institute to: American—Major Lester D. Gardner, Founder of the Institute; Foreign—Sir Richard V. Southwell, Retired.

Fellowships in the Institute to: Robert T. Jones, Aeronautical Research Scientist, Ames Aeronautical Laboratory, NACA; William P. Jones, Superintendent, Aeronautical Division, National Physical Laboratory, England; Brig. Gen. Benjamin S. Kelsey, USAF, Deputy Director, Research and Development Office; Richard V. Rhode, Assistant Director for Research, Aircraft Construction, NACA; Edgar Schmued, Vice-President—Engineering, Northrop Aircraft, Inc.; Adm. John H. Towers, USN (Ret.), President, Flight Safety Foundation, Inc.

The Secretary announced that the Council had elected the following officers of the Institute for 1955: President, Robert E. Gross; Vice-Presidents, Roger W. Kahn, T. Claude Ryan, E. R. Sharp, and Edward C. Wells; Director, S. Paul Johnston; Treasurer, Charles H. Colvin; Secretary, Robert R. Dexter; and Controller, Joseph J. Maitan.

ROBERT R. DEXTER
Secretary

President's Report—1954

IN THE YEAR 1954, during which I have been privileged to serve as President, the Institute has expanded and improved certain of its facilities and services and at the same time has strengthened its financial position. While these aspects of the Institute's affairs are important and necessary, I feel that the most encouraging thing I can report is that the Institute, through the hard work of its Director and staff and through the enthusiastic support of its members, has continued to render very substantial service to the cause for which it was established—advancement of the aeronautical sciences.

The scope and importance of the aeronautical sciences seem to be growing every year, and the opportunities and responsibilities of the Institute are correspondingly increasing. We must continue to expand our important services to our members, to aviation, and to the nation. I am sure that these responsibilities will be met and high professional standards consistently maintained.

Our aeronautical development capabilities are definitely limited by our national engineering resources, including facilities and technically trained personnel. This deficiency in engineering man power which is presently limiting aviation progress is, of course, of major concern to the Institute.

There are, of course, some very good reasons why we need proportionately more engineers today than we did 5, 10,

or 15 years ago. Our technical problems have increased in number and complexity with each new forward step in performance. Not only have the problems become more difficult in every aspect of aeronautical development but the scope of our work has expanded to include many new branches of science with which we were not previously concerned. There is no reason to expect that this trend will not continue.

One of our most important functions is to stimulate and encourage technical education and the maximum development of students and young engineers. Through the facilities of the Institute, these students and junior engineers are encouraged to participate in technical sessions, make original contributions to scientific literature, and learn something of the professional standards and responsibilities.

I have attended student conferences and am glad to report that this phase of the Institute's program is extremely effective and enthusiastically supported. Regional student competitions have been held, and it has been extremely gratifying to see the interest of student engineers and their teachers and the most commendable contributions to aeronautical literature which these young men have produced.

Nothing we can do in the years ahead can be more important or constructive than the maximum support of our Student Branches and regional student conferences.

In support of these vital student activities, Mr. Glenn L. Martin has established the Minta Martin Aeronautical Student Aid Fund of $250,000. This is not a scholarship fund, but the income is used to augment the IAS services to Student Branches, particularly through the annual regional conferences that are now being held throughout the United States every spring. The fund provides prize money for outstanding papers and helps to underwrite the expenses of all such projects.

During the early part of 1954, a second edition of the IAS VOCATIONAL GUIDANCE MANUAL was produced. Over 20,000 copies of the new edition have been distributed through our Student Branches and other channels.

An anonymous donor has made possible the establishment of an IAS research fellowship in flight-test engineering. The first recipient is now completing his course at Princeton University. Selections for next year will be made shortly.

During 1954 a new organization came into being—the Canadian Aeronautical Institute. Both the IAS and the RAeS are collaborating with the new organization as far as possible. The first joint meeting of the CAI and the IAS was held in Montreal in November. Other joint meetings are contemplated.

Planning for the Fifth International Meeting with the RAeS for June, 1955, was largely completed during 1954. Special committees in Los Angeles have been active on local arrangements, and several conferences were held during the year with the RAeS in London.

IAS activities were extended further in the international field by participation in the work of the Advisory Group for Aeronautical Research and Development. The Director and the Secretary attended the Fourth General Assembly in Holland in May, and the Director participated in certain panel discussions in Paris in November.

During 1954 the Institute's income again exceeded its outgo by a substantial margin. We have continued to follow the policy approved by the Council several years ago of augmenting our reserves against future contingencies and of modernizing our equipment. In the latter category, the Los Angeles building has been improved through the installation of adequate cooling and ventilating equipment and the addition of facilities to permit prompt serving of meals to a capacity audience.

The plant improvement program is being continued. At the end of the year the Council authorized the modernization of our printing plant in the New York headquarters, which at present is overloaded and underequipped.

Additions were also made to the Employees Retirement Fund and to our general building maintenance account out of this year's surplus.

An examination of the statement for the past fiscal year which is included in the Treasurer's Report indicates that the IAS ended the year in a sound financial position and that the prospects for the coming year are good. As a result of hard and intelligent work by the local groups, both the Los Angeles and the San Diego facilities wound up the fiscal year "in the black."

I have highlighted only a few of the IAS activities. For those who are interested, further details will be found in the reports of the Director and the Treasurer.

In retiring as President, I wish to express my appreciation for the untiring efforts of the Council, the Director, and the permanent staff in planning and executing the affairs of the Institute. It has been a privilege to be associated with you and with the other Officers during the past year.

Finally, my heartfelt thanks for the fine participation and service that members of the Institute have rendered in committee work, in the preparation and delivery of papers, and in attendance and support at national, regional, and local meetings.

J. L. ATWOOD
President, 1954

Treasurer's Report—1954

MY FIRST TENURE OF OFFICE as Treasurer was in 1937–1938. At that time a statement was made to the effect that I was not pessimistic about the future of the IAS. During the past 18 years I have viewed its financial operations and steady growth with great satisfaction, and the opinion we all had as to the Institute's future was certainly justified.

The consolidated report details the financial operations clearly and concisely. There are several items to be stressed, such as the activity of your Finance Committee, which held several meetings during the year and was in continuous touch with our investment counsel on the Institute's portfolio. The market value of our investments was $129,800 more than the recorded book value, which is an indication of their efforts to conserve principal.

The Minta Martin Aeronautical Endowment Fund was dissolved and its assets distributed in accordance with an order from the Supreme Court of the State of New York on a petition approved by the Council and submitted at the suggestion of Glenn L. Martin. A sum of $250,000 was set up to establish the Minta Martin Aeronautical Student Fund, with the income from the fund to be used to implement the Institute's aeronautical engineering student aid program.

In anticipation of increased operations in our internal print shop, an amount of $6,000 has been reserved for the modernization of equipment. Additions to existing reserve accounts are made as conditions warrant.

The demand for the VOCATIONAL GUIDANCE MANUAL exceeded expectations, and a second edition was printed. This extraordinary cost and others, together with Los Angeles building capital improvements of $28,000, reduced the net income to $25,000 before reserves. The net income after reserves was $2,650.70 and is included in the total net unexpended income as of September 30, 1954.

The West Coast operations were normal, the Los Angeles building showing net income of $2,690 for the year, with San Diego breaking even. The Pacific Aeronautical Library, operating on a $50,000 budget, showed a 6 per cent net income.

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

Statement for the Fiscal Year October 1, 1953, to September 30, 1954

Consolidated Balance Sheet and Operating Statement

ASSETS

Unrestricted:

Cash on Deposit	$122,271.07	
Accounts Receivable	39,836.25	
Advance on Intrafund Accounts	48,979.82	
Deposits and Prepayments	12,307.69	
Investments	769,203.28	
Furniture and Fixtures	5,000.00	
Books, Prints, Models, Medals, etc.	1.00	
Aeronautical Index	1.00	
Total Unrestricted Assets		$997,600.11

Restricted:

The Sherman M. Fairchild Fund	$ 12,359.77	
The G. M. Giannini Fund	5,000.00	
The Paul Kollsman Fund	69,000.00	
The Vernon Lynch Award Fund	38,758.46	
The Minta Martin Aeronautical Student Fund	253,743.21	
The Sylvanus Albert Reed Award Fund	13,596.90	
The Lawrence Sperry Award Fund	13,505.00	
Los Angeles Building Operating Fund	29,080.38	
New York Building Contingency Fund	104,525.24	
Pacific Aeronautical Library Fund	20,964.31	
San Diego Building Operating Fund	7,622.94	
San Diego Building Capital and Library Fund	10,525.36	
Total Restricted Assets		$578,681.57

Facilities:

Los Angeles	$426,065.20	
New York	220,415.26	
San Diego (land leasehold)	176,706.11	
Total Facilities		$823,186.57

LIABILITIES, RESERVES, AND UNEXPENDED INCOME

Unrestricted Funds:

Accounts Payable and Deposits	$ 81,005.85	
Deferred Credits to Income	128,068.93	
Deferred Income—San Diego Building	15,842.77	
Contingency Reserves	218,045.57	
Net Unexpended Income:		
Balance September 30, 1954	554,636.99	
Total		$997,600.11

Restricted Funds (see Assets) $578,681.57

Buildings, Land, and Equipment (see Assets) $823,186.57

Statement of Income & Expenses

Income:

Advertising Revenue	$335,958.80	
Dues and Entrance Fees	236,720.59	
Subscriptions	72,609.10	
Income from Investments	24,553.20	
Miscellaneous	1,036.40	
Total Income		$670,878.09

Expenses:

Publications	$342,004.21	
Salaries (Administrative, Accounting, and Service)	139,297.22	
Employees' Retirement Fund, Reserves, Social Security, etc.	36,643.76	
Libraries (excluding P.A.L.)	31,437.15	
West Coast Offices	30,479.36	
Travel and Meetings	23,002.89	
Building Maintenance and Reserve for Repairs	16,585.67	
Printing, Postage, Telephone, and Telegraph	15,714.84	
Office Supplies and Expenses, Insurance	12,640.52	
Miscellaneous	10,426.09	
Furniture, Fixtures, and Reserve Therefore	9,995.68	
Total Expense		$668,227.39
Net Unexpended Income		$ 2,650.70

The Executive Committee has reviewed and approved the budget for 1954–1955, which operations, it is anticipated, will be substantially similar to those of the past year.

Harris, Kerr, Forster & Company, Certified Public Accountants, audited the books in New York, Los Angeles, and San Diego. A copy of the results of the examination is available to any member on request at the national office.

ELMER A. SPERRY, JR.
Treasurer

Director's Report—1954

THE GENERAL ACTIVITIES of the Institute are covered in the President's Report, and the specifics of our current financial position have been given by the Treasurer. Both indicate satisfactory progress due to continued support by our industry and continued interest and participation in Institute affairs by our membership.

Membership and Section Activities

Quality, rather than quantity, has always been sought by IAS Membership Committees. We believe that the best way to attract new participation in the Institute is by strengthening activities at the Section level rather than by national campaigns. This policy has resulted in a steady growth throughout the years which has brought us at this point to a total graded membership of over 10,000, plus student membership of over 3,000. The detailed breakdown (including the past 3 years) is shown in Table 1.

Some 84 per cent of our membership is enrolled in local Sections throughout the country. The total number of Sections dropped during 1954 because of the transfer of our three Canadian Sections (Toronto, Ottawa, and Montreal) to the newly formed Canadian Aeronautical Institute. One new United States Section (Indianapolis) was activated, bringing the total at year end to 24. Two new Student Branches were formed, giving us a current total of 71.

The trend of Section programs—qualitywise—is most encouraging. Program planning by Section officers is excellent, and many of our Section meetings are producing papers and discussions to national meeting standards. Altogether, 241 Section meetings were held during 1954. Student Branches accounted for 366 more, thus, in aggregate, maintaining a more-than-one-a-day average the year around.

Cooperation among Sections and better coordination of Sections and Branch activities by our Member Services Department showed marked improvement during the past year. More regional inter-Section meetings have been organized, and more interest on the part of our Sections in Student Branch activity in their areas has paid dividends. Publication of Chairmen's News Letters has been an effective means of coordination, and the organization of periodic Section Chairmen's Meetings in connection with our national meetings has been most effective.

Student Branch activities have been greatly strengthened during the year by gifts that made possible the establishment of the Minta Martin Aeronautical Student Fund and the IAS Fellowship in Flight-Test Engineering (see President's Report). The Gabriel Giannini Film Library was expanded, and its first catalog published early in 1955. Also over 20,000 copies of the IAS VOCATIONAL GUIDANCE MANUAL were distributed during the year. The Institute has also cooperated with Boards of Education, Vocational Guidance groups, the Civil Air Patrol, and similar organizations in efforts to interest students in the aeronautical sciences.

Meetings

Technical meetings are, of course, our principal stock-in-trade. The problem of security continues to be bothersome in this connection, but, by proper planning and a high degree of cooperation from the Armed Services and other elements of our Department of Defense, the quality of material presented at all levels continues to be high. The annual meetings in New York in January, in Cleveland in March, and in Los Angeles in June yielded many outstanding papers. The special meeting on turbine transports in Seattle in August was notable, not only for the attendance it attracted, but for the discussion that resulted. The published transactions of that meeting constitute a real contribution to the art.

During 1954, planning for the Fifth International Conference with the Royal Aeronautical Society of Great Britain for June, 1955, in Los Angeles, was active on both sides of the Atlantic.

Publications

Editorial content of the JOURNAL continued at levels established in the preceding year—i.e., 72 pages per issue. Most notable feature was in the interest and volume of "Readers' Forum" items. Established originally to provide for discussion of previously published papers, it has become a medium for exchange of new and original ideas.

The REVIEW is profiting editorially from the advice and assistance of its Editorial Committees established last year. Periodic meetings of these committees give current direction to editorial content. Also, a readership survey conducted during the year has yielded much worth-while information on reader requirements. The response to this survey was unusually high—an indication of the interest in the publications among IAS membership.

As will be noted from the Treasurer's Report, the commercial aspects of REVIEW operations were also satisfactory. Advertising revenue increased again (for the seventh consecutive year), and the prospects for the current year are equally good.

The CATALOG held its own as compared with the preceding year. Advertising in the ROSTER (sold at premium rates to Corporate Members and advertisers) showed a small loss.

Overall, the Institute's publications program operated at a substantial gain of revenue over expense. As has always been Council policy, such earnings are ploughed back into Institute operations or are added to our operating reserve.

Library and Special Services

Activity rates in all IAS libraries continue to be high. Pacific Aeronautical Library leads the list with its daily serving of our Los Angeles area membership with essentially aeronautical information under the guidance of Nell Steinmetz. During the past year, considerable progress has been made by John Glennon and his New York library staff in adapting the New York collections

TABLE 1
Membership Breakdown—Comparisons by Calendar Year

	12/31/52	12/31/53	12/31/54
Temporary Honorary Members	18	15	16
Honorary Fellows	26	28	30
Fellows	191	197	199
Associate Fellows	699	757	829
MEMBERS	3,511	3,878	4,212
Associate Members	399	440	482
Historical Associate Members	70	74	102
Technical Members	4,238	4,329	4,410
Total Graded	9,152	9,718	10,280
Student Members	2,796	2,672	3,110
Total	11,948	12,390	13,390

more nearly to meet the needs of the East Coast industry. A modest but growing library activity has been re-established in our San Diego facility.

Related to our libraries is an operation established at San Diego during the past year under an Air Force contract to catalog all films of technical interest in aeronautics. This unit is operated by Roy Elliott, assisted by a small staff, under ARDC cognizance.

Historical interest in aeronautics has been furthered during the year both in the East and West. Catherine Schneider, in charge of special exhibits and archives in New York, has been working on programs designed to foster interest among high school and Civil Air Patrol groups. In Los Angeles, the local historical groups have held numerous meetings throughout the year and have continued the publication of AERONAUTICA.

Facilities

Modernization of IAS plant and equipment has continued throughout the year. Kitchen modification in the Los Angeles building was completed, and air conditioning of the auditorium and conference rooms (eliminated when the building was constructed for budgetary reasons) was authorized by the Council and installed. A program for relocation and modernization of our New York printing plant was presented to and approved by the Council and will be carried out in early 1955.

It will be noted from the Treasurer's Report that both the Los Angeles and the San Diego facilities ended the fiscal year "in the black." This was the result of hard and intelligent work on the part of the local groups involved.

General

During the past year, the Institute has collaborated closely with the work of AGARD (a NATO organization), particularly in the field of aeronautical documentation. The IAS was represented (by USAF invitation) at AGARD meetings in Holland in May and in Paris in November. A project for the establishment of an improved international aeronautical abstracting service is under active consideration.

The success of IAS objectives during the past year could not have been accomplished without the active interest and whole-hearted collaboration of four major groups—viz. (1) the aeronautical industry which supports our effort directly or indirectly; (2) the members of our Council whose personal interest provides sound policy direction to our operations; (3) the individual members who contributed to activities at all levels; and (4) a loyal and well-integrated staff who labor day in and day out to make this organization work. My personal thanks to them all.

S. PAUL JOHNSTON
Director

IAS Plaque Unveiled at Columbia University

On December 22, a plaque given to Columbia University by the Institute of the Aeronautical Sciences was unveiled in the entrance lobby of Columbia's Pupin Physics Laboratories by Major Lester D. Gardner, IAS Founder. Speaking briefly at the unveiling, Major Gardner recalled the part played by Columbia in the Institute's early years and stated that the Institute had held its Founders' Meeting and many subsequent meetings in Pupin. The plaque was accepted on behalf of Columbia University by its President Grayson Kirk, before a group that included university officials and IAS Founder Members.

The plaque, which is mounted in Pupin's entrance lobby, bears the following inscription: "In appreciation of its generous hospitality for many years, this plaque is given to Columbia University in its bicentennial year by the Institute of the Aeronautical Sciences, which was founded in the Pupin Physics Laboratories in 1932."

Lester D. Gardner before the newly unveiled plaque at Columbia University.

At the conclusion of the unveiling ceremony, luncheon was served in the Men's Faculty Club at Columbia. Major Gardner, when called upon for additional remarks, spoke in praise of Dr. George B. Pegram, Special Adviser to the President and Vice-President Emeritus, Columbia. It was primarily through the offices of Dr. Pegram that the facilities of Columbia, and the Pupin Physics Laboratories in particular, were made available to the members of the Institute of the Aeronautical Sciences.

Necrology

Willard A. Pollard III

Lieutenant Commander Willard Averell Pollard III, USN, TMIAS, died at sea November 14.

Born in Washington, D.C., May 12, 1922, he attended the District's Roosevelt High School between 1936 and 1939. He matriculated in July of 1940 at the U.S. Naval Academy and was graduated from there 3 years later with a B.S. degree in Electrical Engineering. He received a second B.S., in Aeronautical Engineering, at the U.S. Naval Postgraduate School in 1950. He was granted a Master's degree in Aeronautical Engineering by the University of Minnesota in 1951; his thesis for this degree was on "A Study of the Effects of Some Nonlinear Stability Derivatives on the Lateral Motions of Aircraft."

Commander Pollard, a Naval Aviator, was on active duty at the time of his death. He is survived by his widow, Ione Iverson Pollard.

Harold R. Uhrich

Harold R. Uhrich, MIAS, Propeller Development Engineer for S. Morgan Smith Company, was killed late last December in the crash of a company airplane in which he was riding as a passenger. He had celebrated his forty-second birthday only a few days before the accident.

A native of Millersville, Pa., Mr. Uhrich received his B.S. degree in Mechanical Engineering from The Pennsylvania State College (now University) in 1933. He attended New York University in the 1936–1937 academic year and received his diploma as an Aeronautical Engineer.

From 1933 to 1936, he worked as Assistant Superintendent of Safe Padlock and Hardware Company. After completing his work at N.Y.U., he became first a Design Engineer and later Chief Engineer for Sensenich Propeller Company. In 1945, it was estimated that of all fixed-pitch wood propellers meeting U.S. Navy and USAAF acceptance tests for installation on liaison and primary training planes, 90 per cent were designed by Mr. Uhrich.

In the late 1940's, he joined the Aeromatic Propeller Department of

(*Continued on page 29*)

President
Robert E. Gross
President and
Chairman of the Board
Lockheed Aircraft Corporation

Vice-President
Roger W. Kahn
Service Manager and Test Pilot
Grumman Aircraft Engineering
Corporation

Vice-President
T. Claude Ryan
President
Ryan Aeronautical
Company

IAS Officers for 1955

Staff Officers for 1955

S. Paul Johnston, Director

Robert R. Dexter, Secretary

Joseph J. Maitan, Controller

Vice-President
Edward R. Sharp
Director
Lewis Flight Propulsion Lab., NACA

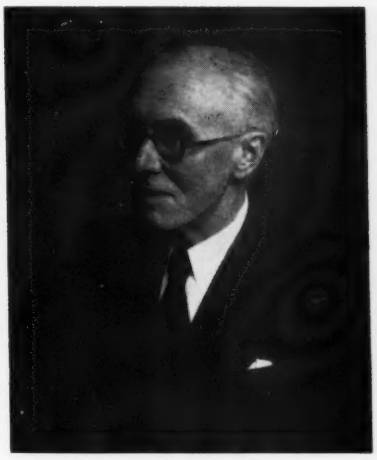
Vice-President
Edward C. Wells
Vice-President—Engineering
Boeing Airplane Company

Treasurer
Charles H. Colvin
President
Colvin Laboratories, Inc.

American Honorary Fellow
Lester D. Gardner

Honorary Fellows for 1954

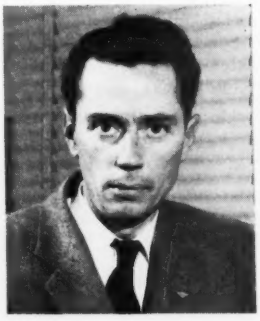
Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. Not more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellow in any one year.



Foreign Honorary Fellow
Sir Richard V. Southwell

Fellowships in the Institute—1954

Fellows of the Institute of the Aeronautical Sciences shall be those who have attained a position of distinction in aeronautics and made notable and valuable contributions in one of the aeronautical sciences or aeronautical engineering.

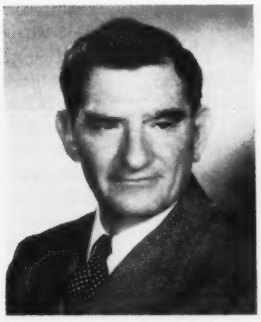


Robert T. Jones
Aeronautical Research Scientist
Ames Aeronautical Laboratory, NACA

Dr. William P. Jones
Superintendent, Aerodynamics Division
National Physical Laboratory, England

Brig. Gen. Benjamin S. Kelsey, USAF
Deputy Director, Research and Development Office, USAF

Richard V. Rhode
Assistant Director for Research
Aircraft Construction, NACA



Edgar Schmued
Vice-President—Engineering
Northrop Aircraft, Inc.

Adm. John H. Towers, USN (Ret.)
President
Flight Safety Foundation, Inc.

IAS Awards and

Dr. James P. Henry
Chief, Acceleration Unit, Aero Medical Laboratory
Wright Air Development Center, USAF

The John Jeffries Award

This award honors the memory of Dr. John Jeffries, an American physician who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785 and on a previous voyage made the earliest recorded scientific observation from the air. This award, which has an honorarium of $200, was established by the Institute in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine.

Presented to JAMES P. HENRY, M.D.

"For outstanding contributions to the advancement of aeronautics through medical research."

Dr. James P. Henry, Research Physiologist and Chief of the Acceleration Unit of the Aero Medical Laboratory at Wright Air Development Center, has made unique and varied contributions to aeronautics since 1943. He is credited with the practical development of the partial-pressure high-altitude suit for pilots, elucidation of the physiology of negative acceleration, and fundamental contributions to the physiology of positive acceleration and the physiology of blood-volume control.

Starting his work on the partial-pressure high-altitude suit at the University of Southern California's Aero Medical Laboratory, Dr. Henry attacked a problem that German scientists had abandoned as impractical and developed a successful suit operating on the pressure-breathing principle with supplementary use of counter pressure. He personally tested this equipment at extremely high altitudes (up to 75,000 ft. simulated altitude) where the accidental malfunctioning of this experimentally untried device would have placed his life in jeopardy. His lightweight, porous, maneuverable suit has proved to be the only immediately available answer to the need for emergency pressurization of the pilot.

Dr. Henry was Senior Project Engineer in establishing the Aero Medical Field Laboratory, now called the Space Biology Laboratory, at Holloman AFB, N.M.

Hermann B. Wobus
Meteorologist, Project AROWA, U.S. Navy Fleet
Weather Central, Norfolk, Va.

The Robert M. Losey Award

Established in 1940, this award honors the memory of Capt. Robert Moffatt Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. This award carries an honorarium of $200.

Presented to HERMANN B. WOBUS

"In recognition of outstanding contributions to the science of meteorology as applied to aeronautics."

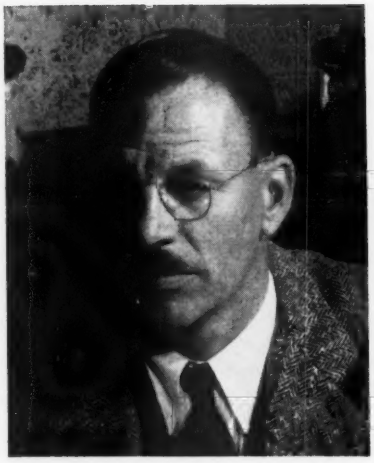
Hermann B. Wobus, Meteorologist of Project AROWA (Applied Research; Operational Weather Analyses), U.S. Navy Fleet Weather Central, Norfolk, Va., has been cited for his technical leadership and guidance in applied research and for developing new techniques of weather analysis and new methods of clearly explaining meteorological conditions to flight personnel.

Mr. Wobus played a major role in compiling and evaluating the Constant Absolute Vorticity Trajectory Tables, which deal with winds and the movement of wind fields. They are used in preparing the accurate high-altitude weather forecasts needed for planning flight operations. These tables are related to a mechanical computer that he invented while employed by the U.S. Weather Bureau.

Mr. Wobus has done extensive research on the jet stream. High-speed airplanes, rather than sounding balloons, now probe the jet stream and provide more accurate data than has hitherto been available. Mr. Wobus was instrumental in coordinating the work of AROWA, the University of Chicago, and the Naval Air Test Center in obtaining and analyzing these data.

Presentation of complex meteorological data has been greatly simplified, without sacrificing accuracy, by a new thermodynamic diagram called the AROWAGRAM which Mr. Wobus computed and designed for the Navy.

Honors for 1954



Dr. Clark B. Millikan
Director, Guggenheim Aeronautical Laboratory
California Institute of Technology

The Sylvanus Albert Reed Award

For a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics.

The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the Institute, made an endowment to the Institute in 1933 to provide an annual award with a certificate and honorarium of $250. The recipient of this award is chosen by the ballot of the American Honorary Fellows and Fellows of the Institute.

Presented to DR. CLARK B. MILLIKAN

"For his contributions to fluid mechanics, airplane aerodynamics, and wind tunnel technology, and for research leadership and guidance in the aeronautical sciences."

Dr. Clark B. Millikan, Director of Guggenheim Aeronautical Laboratory at California Institute of Technology, has been in charge of wind-tunnel testing at C.I.T. since 1935 and has been Director of the Southern California Cooperative Wind Tunnel since it began operations in 1945. He is Chairman of the Jet Propulsion Laboratory Board at C.I.T. Dr. Millikan's work has provided theoretical and experimental additions to aeronautical technology in the fields of (1) fluid mechanics; (2) airplane aerodynamics; (3) wind-tunnel testing, particularly high-speed tunnel testing; and (4) jet propulsion and guided missiles.

At CalTech, Dr. Millikan has developed and leads a research facility that is up to date, extensive, and extremely useful to aeronautics and the aeronautical industry. In addition to publishing some 30 technical papers, he is Coeditor of the GALCIT Aeronautical Series and author of the first volume. He has served on many important scientific and Government committees, and, as Professor of Aeronautics, he has inspired hundreds of students to achieve notable success in the engineering profession. An Honorary Fellow and Past-President of IAS, Dr. Millikan delivered the Wright Brothers Lecture in 1939.

A. Scott Crossfield
Aeronautical Research Pilot, NACA High-Speed
Flight Station, Edwards AFB, Calif.

The Lawrence Sperry Award

For a notable contribution made by a young man to the advancement of aeronautics.

This award was endowed in 1936 by the sister and brothers of the late Lawrence Sperry, pioneer aviator and inventor, who died in 1923 at the age of 31. It provides an annual certificate of citation and an honorarium of $250 to the recipient selected by the Board of Award.

Presented to A. SCOTT CROSSFIELD

"For important contributions in aeronautical flight research, especially at transonic and supersonic speeds up to Mach 2."

A. Scott Crossfield, 33 years old, breaks the sound barrier as a daily chore. A research pilot attached to NACA's High-Speed Flight Station at Edwards AFB, Calif., he became the first man to fly at twice the speed of sound on November 20, 1953, when he guided the rocket-powered D-558-II at 1,327 m.p.h. in a test flight high above the desert.

In addition to logging more than 2,500 hours as a pilot, mostly in Navy fighters, Mr. Crossfield is an Aeronautical Research Scientist with a Master's degree in Aeronautical Science from the University of Washington. He was graduated from Washington as an aeronautical engineer in 1949. With NACA since June, 1950, he has flown almost every type of airplane used by NACA for high-speed flight research: the X-1, X-4, X-5, XF-92A, D-558-I, and D-558-II. The valuable scientific data obtained in free flight at transonic and supersonic speeds are of a type that cannot effectively be obtained by any other means.

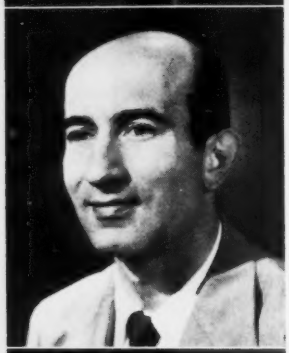
Mr. Crossfield was coauthor of two papers presented at the NACA High Speed Conferences in 1951 and 1953. Last October he presented a paper entitled "Flying Techniques on Research Airplanes" at a joint meeting of the Canadian Aeronautical Institute and IAS in Montreal. He also gave a paper at the Test Pilots' Round Table connected with a recent meeting of NATO's Advisory Group on Aeronautical Research and Development.

Newly Elected Members of the Institute Council

Eastern Area (1-year term)

Louis Fahnestock
Director—Engrg., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

Capt. William C. Fortune
USN, Director
Naval Air Experimental Station, Philadelphia, Pa.



Central Area (1-year term)

Eugene J. Manganiello
Assistant Director
Lewis Flight Propulsion Laboratory, NACA

John H. Meyer
Chief of Structures
McDonnell Aircraft Corporation

Western Area (1-year term)

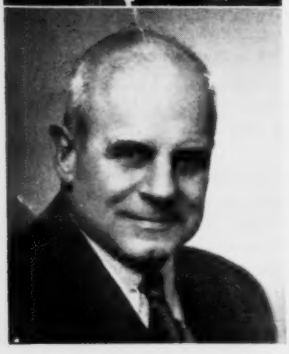
Harold Luskin
Asst. Chief—Aerodynamics
Santa Monica Div., Douglas Aircraft Company, Inc.

John R. MacGregor
Research Coordinator
California Research Corporation

Council Members (3-year term)

W. A. M. Burden
Partner
William A. M. Burden & Company

George F. Chapline
V-P and Gen. Mgr., Fairchild Engine Div., Fairchild Engine & Airplane Corp.



(Bottom left)
James H. Doolittle
Vice-President
Shell Oil Company

(Bottom right)
Elmer A. Sperry, Jr.
V-P and Treasurer
Sperry Products, Inc.

Charles J. McCarthy
Chairman of the Board
Chance Vought Aircraft, Inc

(*Continued from page 23*)

Koppers Company, Inc., as Chief Analytical Engineer; he later was made Chief Engineer. In 1952, he became associated with S. Morgan Smith Company.

He is survived by his widow, Elsie F. Uhrich, and two children.

News of Members

▸ **Frank E. Carroll, Jr.** (M), Chief Engineer, United Aircraft Products, Inc., is serving during the 1955 calendar year as Vice-President—Aircraft Powerplant Activity, Society of Automotive Engineers.

▸ **Leston P. Faneuf** (AM), General Manager and Treasurer, Bell Aircraft Corporation, has been elected Vice-President and Treasurer of Bell's newly acquired and wholly owned subsidiary, Hydraulic Research and Manufacturing Company. (See Bell Aircraft item, p. 68.)

▸ **Dr. Clifford C. Furnas** (F) was inaugurated on January 7 as Chancellor of the University of Buffalo.

▸ **Robert E. Gross** (AM), IAS President and President and Chairman of the Board, Lockheed Aircraft Corporation, was given the Los Angeles Advertising Club's Hourglass Award for "continuing progress in aeronautics."

▸ **Stanley Hiller, Jr.** (TM), President, Hiller Helicopters, has been elected the 1955 Chairman of the Helicopter Council, Aircraft Industries Association of America, Inc.

▸ **Dr. W. Randolph Lovelace II** (F), Director, Lovelace Foundation for Medical Education and Research, will direct The Institute of Nuclear Medicine, which is being established in Albuquerque, N.M., by funds appropriated by General Dynamics Corporation to the Lovelace Foundation. The Institute of Nuclear Medicine will be devoted to nuclear applications in the fields of curative and preventive medicine and public health. Two of its functions will be the establishment of a special reference library of world literature on nuclear medicine and the periodic publication of a *Journal of Nuclear Medicine.*

▸ **Dr. Charles H. Lutz** (M) has resigned as Assistant Project Manager of Designers for Industry, Inc., in order to become President of his own organization, Atomic Energy for Industry, Inc., of Cleveland. Dr. Lutz remains affiliated with Designers for Industry as a Special Consultant and Associate Staff Member.

▸ **Wilbur S. Mount** (M), General Manager, Aviation Sales Department, Socony-Vacuum Oil Company, is Vice-Chairman for 1955 of the Aviation Technical Service Committee of the American Petroleum Institute's Division of Marketing.

▸ **Robb C. Oertel** (AM), Manager, Aviation Department, Esso Standard Oil Company, is the 1955 Chairman of the Aviation Technical Service Committee of the Division of Marketing of the American Petroleum Institute.

▸ **Edward R. Sharp** (F), Director, Lewis Flight Propulsion Laboratory, NACA, served as Honorary Chairman of the National Model Plane Show, held in Cleveland February 21–22. Dr. Sharp is an IAS Vice-President.

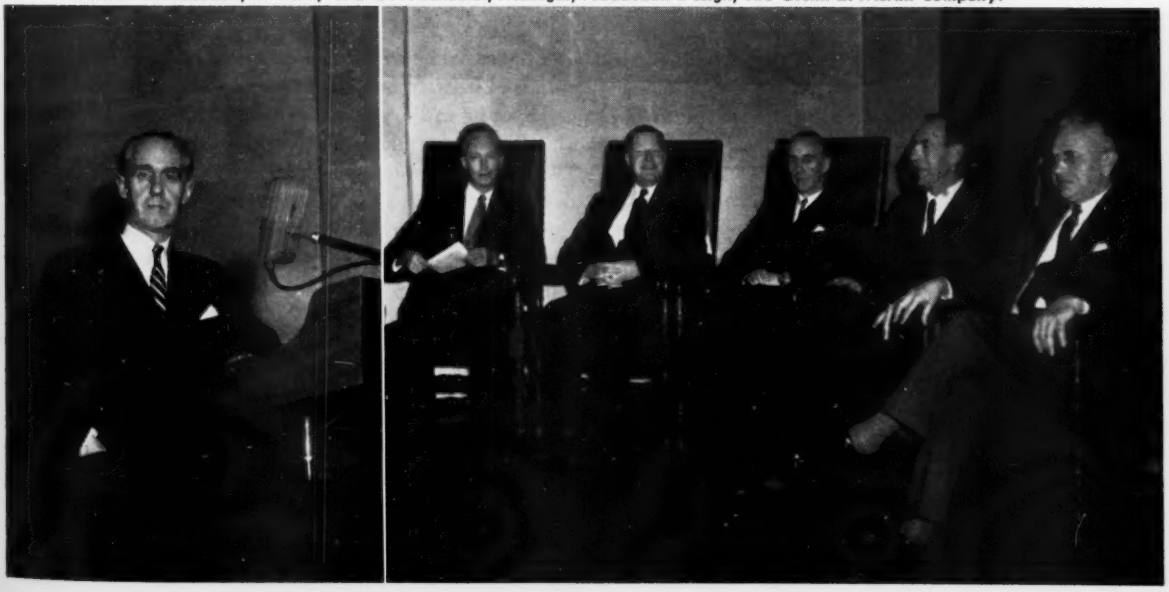
▸ **Dr. Theodore Theodorsen** (F) has joined the Fairchild Engine Division of Fairchild Engine and Airplane Corporation as a Consultant.

▸ **Walter Tydon** (M), Chief Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation, was re-elected Chairman of the 1955 Air Cargo Advisory Committee, National Security Industrial Association.

▸ **Charles H. Webber** (M) has been elected Secretary-Treasurer of Sturgess, Inc., a manufacturing affiliate of Pacific Scientific Company. Mr. Webber is Vice-President and Assistant General Manager of Pacific Scientific.

(*Continued on page 66*)

Left, **Bo Lundberg, Director, Aeronautical Research Institute of Sweden, is shown during his presentation of the Eighteenth Wright Brothers Lecture in Washington, D.C. His paper, "The Fatigue Life of Airplane Structures," was delivered on December 17 before some 350 aeronautical engineers and scientists. Mr. Lundberg repeated this lecture in Los Angeles on December 20 and in Cleveland 2 days later.** ***Right,*** **also on December 17, Mr. Lundberg is shown with the three discussors of his paper and J. L. Atwood, President of North American Aviation, Inc., who chairmanned the program. Mr. Atwood was at that time the incumbent IAS President. Seated from *left to right* are: Mr. Atwood; William Littlewood, Vice-President, American Airlines, Inc.; Mr. Lundberg; Richard V. Rhode, Assistant Director for Research, Aircraft Construction, NACA; and O. J. Schaefer, Manager, Production Design, The Glenn L. Martin Company.**



IAS President 1955

Robert E. Gross

President
Lockheed Aircraft Corporation

We all extend a hearty welcome to the new IAS President as he begins his term of office. Another extremely busy man, he has nevertheless indicated great interest in participating in the affairs of the Institute, and we are looking forward to another active year under his leadership.

As Bob Gross said in his acceptance speech on Honors Night, although he is not a technical man himself, he has always been a student of men. He has great capacity for understanding men and their needs. He is vitally interested in engineers as people and in fostering educational programs that will turn out well-rounded men, as well as capable scientists and engineers.

Outstanding among the coming events of 1955 is the Fifth Anglo-American Conference set up for late June in Los Angeles. Our President will find many old friends among the visiting British delegates.

As he enters upon his job as President of the Institute for 1955, the membership and the staff pledge to him their utmost in cooperation. Welcome aboard!

Editorial

IAS President 1954

J. Lee Atwood

President
North American Aviation, Inc.

As Mr. Atwood stepped down from the presidency at the January Honors Night Dinner, he was able to report a successful year of operation in all IAS departments. Membership was still on the increase, meetings had been many and varied, and the Institute's financial position had never been better. During the year, continual improvement had been made in modernization of our plant and equipment, and a program for continuation during 1955 had been laid down.

We are all indebted to Lee Atwood for the contribution he has made to IAS affairs during his presidency. As head of one of the busiest aircraft factories in the world, he has had much to occupy him, but he has always found time to take a most active part in the work of the Council and in attending our meetings—local, regional, and national.

He rates a vote of thanks from the entire membership. We are all looking forward to his continuing assistance as a Council Member during 1955.

Honors Night Dinner Address

by

Roger Lewis

Assistant Secretary of the Air Force (Materiel)

"Aviation, like other arts and sciences, while constantly progressing, does so at varying rates, providing plateaus from which we can take stock and re-orient our paths toward our goals. We are on one of those plateaus now.

"On Honors Night 1955, the United States is at peace. It is an uneasy peace, to be sure, but, for the first time in many years, we have no formal war. We also, for the first time in peace, have a great military establishment—a force in being. In the Air Force we are well along toward the realization of our 137-wing strength. We now have about 120 wings active, most of which are combat wings, with all fighters jets and the conversion of bombers to jets well under way.

"What is more important, although we will not complete our full 137-wing force for another 2 years, is that we have in fact started to replace existing aircraft with improved equipment. Successors to some of our first-line fighters and bombers are already in the production line. And looking still further down the road, improvements of these are in the lab and on the drawing board.

THREAT—ECONOMIC AS WELL AS MILITARY

"National policies, under which we must plan our forces, have been clearly stated. The President has declared that we are living in an 'age of peril.' This age is one of indefinite duration—perhaps 50 years or more ahead.

"Previously, our force planning had been based upon the concept that we faced successive moments of greatest danger, and the build-up of our forces was based upon an urgent requirement that we achieve a military posture of strength by given successive dates.

"The differences between the two policies in our weapons planning are fundamental. Under the former policy, all our energy was concentrated on creating an inventory. Under the new policy, the emphasis is on maintaining ready forces of superior quality at all times for an indefinite period ahead. This throws the emphasis on a continuous search for, and addition of, improved weapons to our inventory indefinitely. It is a never-ending new look.

"Another keystone of national policy is that the threat against us is more than a military threat—that the military planner, in establishing forces and planning equipment, must recognize that economic strength, an expanding economy, and an improved standard of living are as vital to our security as our military strength. We must have security in arms, but the security cannot be bought at the expense of a weakened economy. Defeat through economic ruin can be as disastrous as defeat through failure at arms.

"Based on these policies, the Joint Chiefs of Staff have assigned missions and determined force sizes. The Air Force knows its job—its job is how to do it well.

"My purpose is to discuss some of the problems of assuring qualitatively superior weapons through this indefinite age of peril. I propose to do this by reviewing some of our past deficiencies, discussing the general nature of the problems presented by the technological age in which we live, and suggesting a general approach to our problem. Not only is the time appropriate for such a discussion, but in this group—the opinion-forming segments of the military, scientific, and industrial fraternity—I have not only an interested but a responsible audience

Lessons from the Past

"The records show that the United States has been eminently successful in adapting its military power to take advantage of the peculiar technological character of its society. However, the same records also show that the adaptation has been accompanied by considerable friction. There have been slippages, lost opportunities, and costly errors in concept and timing.

"We can always learn from the past, and an examination of difficulties in past programs reveals that we have occasionally suffered from three basic faults. The first is poor conception. Occasionally, and usually under pressure, we have bought interesting weaponry that either did not fill a clear military need or was inadequately thought out technically. In such cases, no amount of improvisation or patchwork succeeded in putting it right. Such programs were wasteful, but what was more serious was the fact that completion of a poor weapon weakened us. If it could be used, although poorly, it was but a substitute for something that should have been provided. If it did not work, it, of course, created a deficiency—a hole in the general weapons inventory.

"Second, we have frequently suffered from not being resolute and decisive in changing or terminating projects that, although sound in concept, ran into trouble as we proceeded with them—or were superseded by new developments offering better, cheaper, or faster answers to our need. It is the nature of our business that we should try things that may not work, or try more than one way of accomplishing the same end, or occasionally gamble on a major technical advance. This is necessary and good and should be continued vigorously, but, if we are to make the most of this exploratory approach, it is mandatory that we be firm, ruthless, and quick to halt projects that do not confirm their early promise. This is not just a matter of money. The insidious part of staying with a bad idea is that it prevents you from moving ahead with a good one.

"A third broad area with which we have had trouble is the area of weapons planning and control. Many a fine weapon that has been produced at great cost has worked out well but still did not add one ounce to the air power for which it was bought. Because of some deficiency, it could not be put into the inventory as planned. A late air weapon—no matter how fine—is often like a ticket to yesterday's ball game.

"An airplane is not necessarily an air weapon. It must have the right engine, the right fire control, the right armament; it must work, and people must know how to use it.

"If we do not evaluate properly and take all of these factors into account in our planning, we have air frames in the factory yard and not air weapons on the air base, which is our goal.

"Similarly, there is no air power in equipment that has to be taken from combat wings and put through lengthy modification to realize its initial promise. Such practices, always wasteful, are often necessary in times of emergency, but they are intolerably expensive to forces in being.

"These deficiencies are the often unavoidable products of the crash program approach to weapons production. If the political or military situation demands crash programs, they are essential and must be tolerated. While the waste in time and money is great, it is nothing to the alternative risks to national security.

"However, in the age of peril, it is clear that we must avoid any haphazard crash program. Not only would this cost too much if we are to have an expanding economy, but the very military facts of life make it impossible for two reasons: First, nuclear weapons and long-range airplanes on both sides mean that we must maintain a high level of readiness rather than a series of peaks. Second, the complicated weapons of today are taking continually increasing lengths of time. Clearly, we shall have neither qualitative superiority nor readiness if we try to program to the ebb and flow of the military and political situation and ignore the fundamentals of the technology from which we draw our strength. What are some of these fundamentals?

Our Technological Age

"We all know what is meant by a shrinking world. This is the effect of developments in transportation and communication. The more we use what we have, the more we require. Thus we have generated a self-activating cycle that will continue to shrink the world. The technical processes by which we solve one set of problems tend to generate more problems than they solve, thereby continually expanding our technical world, as in an inverted pyramid. A new invention or a new technique does not automatically outmode another. It only outmodes that which fails to adapt itself. Moreover, the more technology demonstrates what it can do, the more it is called upon to do. This results in complexity of equipment.

"Avoidable complexity can, in time, be reduced, but it cannot be denied, and its effect upon military weapons is a matter of great significance. A simple example will illustrate.

"Let us assume that a fighter airplane is to destroy another airplane in combat and that to do this it must do a number of things in sequence. It must position—that is, reach the combat area under specified conditions; it must search—locate the proper target; it must close—a very complex operation; and then kill.

"The probability that it will be successful in this mission is the product of the individual probabilities of each step involved in this operation. If the chance of accomplishing any one step is low, then the chance of a successful mission is correspondingly low.

"Two fundamentals of great importance are illustrated. First, the equipment necessary to perform this task is enormously complicated, creating unimaginable problems of field maintenance, repair, and replacement. Combat capabilities become extremely sensitive to seemingly minor logistic and technical difficulties.

"Second, it shows that the entire tactical operation of the aircraft, and the technique to be employed, must be viewed in its entirety as a complete system. This is the so-called weapons systems concept. It has begun to receive wide recognition, and it must continue to do so.

"However, in our technological age, diversity and complexity, as such, should not concern us, since it is obvious that with experience we can fairly well adjust ourselves to its effects. It is, rather, rate of change, especially rapid rate of change, wherein our great competitive problem with our potential enemy arises in the maintenance of superior military effectiveness. The question constantly before us is, how can we harness the forces of unforeseen change and do it better than our military and political opposition? Clearly, we cannot stop change. We can only guide and exploit it.

The Priceless Commodity

"The popular bromide that time can be bought can be accepted only with great caution and understanding. Money will not in any real sense buy scientific inventiveness. It can only expedite the process of technical demonstration and operational adoption.

"The principle of the steam engine was visualized in 1756, but the first steam locomotive did not appear until 1803. A guided missile flew in the period of World War I but is still relatively in the future, operationally. Jet engines were running before World War II, but they reached only limited application in the last days of the war.

"Reliance on the false premise that time can be bought can lead to disaster.

"The Germans fell victim to this fallacy in World War II. During the 1930's, German industry produced a technically advanced military force. It had no obsolescent inventory to becloud the picture, and the Luftwaffe plainly had the time to plan carefully and mold the new German military techniques that were the basis of their war planning. They expected the war would be over before the slow pace of our own technology could alter their situation; therefore, they did not enter the war with an active and mobilized long-term development program or with the means for maintaining the techno-military partnership at all planning levels. They entered the war with the most modern military force but without the capacity to maintain its qualitative superiority.

"They did produce, at the end of the war, some remarkable technical experiments, but on a frantic basis, and they could never really exploit much of what they were doing before the whole scientific and production structure was captured by the Allies.

"Our own conduct has been far from safe. In the middle 1940's we had let our guard down technically as well as in almost everything else pertaining to a military posture. It is true that we had a conglomeration of development projects, but there was little sense of direction, guidance, or purpose—little feel for the strategy of timing.

"Along came Korea, and within a few years the research and development activity within the services, as measured in dollars, had nearly trebled. What is wrong with that? Only that no experimental program can grow that fast and still be robust.

"Fortunately, we have done away with a 'particular crisis' target date. We are now able to consolidate our development programs into a more healthy state, recasting them in terms of realities. The job will be done better, and the cost will be less. We now realize that the size and impetus of research and development programs cannot be adjusted up or down according to the particular fortunes of a given year or in accordance with what an enemy may or may not be doing.

Profit and Loss

"We have seen that we have no time to lose—neither do we have wealth that we can afford to waste. Rich as we are in man power and natural resources, we must recognize that there is a limit to what a country with 7 per cent of the world's population and 6 per cent of the world's usable land mass can do. It must be clear that we cannot afford to do everything, and in our planning we must learn to differentiate between experiments that have the potential only of showing us how better to take the next technical step and those experiments that in themselves, if successful, constitute the advance that should be incorporated into the military inventory.

"We must learn also to differentiate between the meaning of 'possibly' and 'probably.' We cannot afford to adopt new techniques if the military worth will not pay off, regardless of the apparent technical attractiveness of the proposal. We cannot afford, pleasant as it is, research, development, or engineering on a military scale that does not have a fair prospect of placing in our hands a military advantage.

Fallacy of the Technological Proprietary Interest

"In considering these time-cost factors, something has to be said about the so-called 'technological proprietary right'—the assumption that a nation might have a monopoly or even an advantage in inventive capability. Such an assumption could have grave consequences. The airplane itself came into existence in several places almost at once. Radio and motion pictures were born in so many places that no nation can claim the honor of first invention. The Soviet Union, contrary to our best predictions, exploded an A-bomb not long after we did. Later, it confounded some of us with the MIG-15, an airplane that they were able to develop and make available in vast numbers—again, to the surprise of many.

"We must not be so naive as to take comfort from imagined technological superiority. Neither must we base our programs on what we may or may not see of what our potential enemy is doing. Our approach to

superior weapons must be positive—based on the best that we can do to wring from our technological society the best that is in it. There are no monopolies in science. No counterpuncher is ever a champion.

Strength Through Conflict

"In considering the problem of maintaining weapons superiority it would be folly to be blind to the essential conflict between the interests of science and engineering on the one hand and those of production and the inventory on the other.

"The military has continuously vast, unsatisfied wants. The production line requires stability if we are to get anything built, while science and engineering must continuously fiddle and experiment if they are to exploit their unfolding resources.

"Research and development is inherently controversial. Rather than factual, it is a search for facts and causes dissension among the partners. We are pressed, on the one hand, to let science have its head and, on the other, to keep engineers from their everlasting experimentation in the production line. Development activity is cautioned not to duplicate its own work, yet it is paid to make duplicate approaches to the same problem. It is inherently wasteful and inefficient, and yet our ultimate military efficiency depends squarely upon the processes.

"This leads, as it has in the past and inevitably will in the future, to conflict. While the military, industry, and science have certain exclusive areas of interest, the nature of our technological age is such that there is a broad interface of conflicting interests.

"In broad terms, strength comes from conflict. Just as strength grows out of independence among the three branches of the American system of government, so the flow of quality weapons comes from a conflict of the need of the military, the unfolding of science, and the capacity of industry. The essence of our success so far, and our hope for the future, lies in our ability to live with this controversy and use it constructively.

"Air Force organization recognizes this essential conflict through its Research and Development and Air Materiel Commands, both of which report directly to the Chief of Staff. The establishment of a separate command and the appointment of a Deputy Chief of Staff for Development reflect the importance attached to scientific research and development activity in air weapons and techniques.

"The reduction of this command structure to practice has not been without difficulty—as might be expected from changes of this magnitude in an organization the size of the Air Force. But it is our way—the way we see by which we can get the best of two worlds.

"Actually, it is working well. As policy and procedure are clarified through experience, we see our research and development people moving more boldly forward in the field of their primary responsibility and those responsible for production and procurement doing a better job in their special field. Of course there is friction. The nature of our problem demands it, but the area is getting smaller as each command understands the scope and difficulties of its special mission and goes about doing it.

"There are no simple, easy solutions or panaceas to the problem of maintaining qualitative superiority in our air weaponry in the age of peril. Our experience cautions us to be suspicious and critical of any such suggestion. However, understanding and respect for our experience and the principles discussed do provide guidance for the future.

"To conclude, I would like to restate these points briefly.

"(1) We must recognize that we live in changed times, requiring changed emphasis in our planning. We have gone from an era of scarcity to an era of plenty in our weapons inventory. Up to now, our compromises have been forced to favor quantity. Henceforth, we can afford to compromise in favor of quality, and we must do so. Expressed another way, we have been plagued by too little, too late. In the future, with large forces in being, we can be as easily plagued with too much, too soon, if we do not plan carefully.

"(2) Ours is a technological age with laws that demand understanding and observation. Our technological world is one of greatly increasing diversity and complexity, and its rapid rate of change is a plague upon us. Further, we must perform our tasks within narrow limits of cost and time. These laws and limitations are immutable and compel us to plan with infinitely greater care and much further into the future than has been our practice.

"(3) Conflict is inherent in the interests of the scientist, the militarist, and the industrialist. There is strength in the conflict if it is used. But it requires understanding, communication, and mutual respect among the partners if it is to contribute to our common goal. It is a marriage of equals. It is an adult relationship.

"Science, industry, and the military share equally the responsibility for quality air power in the age of peril. Each must recognize that technical decisions made today irrevocably commit us militarily years ahead. The penalty for carelessness, inattention, lack of understanding and coordination—failure to recognize the principles we have discussed here could lead as surely to disaster for ourselves, our children, or our grandchildren as carelessness in the air battle.

"This is the air age. It is also America's age. We are great because of the application of our principles of personal freedom and free enterprise, backed up by a love of liberty and a desire for a better world for all mankind. There is nothing but great promise ahead if we will but understand the nature of our age and continue to apply our moral principles in its fulfillment."

Test Cell Augmenter Design

RICHARD D. LEMMERMAN* AND HAROLD J. LOCKWOOD†

Industrial Sound Control, Inc., and Trinity College, Respectively

Introduction

ONE OF THE MOST CRITICAL PROBLEMS in the design of jet-engine test cell and run-up silencing equipment is the accurate control of secondary air cooling. Extremely high jet-engine exhaust temperatures require substantial cooling in order that the gases may be adequately handled by available high-efficiency, sound-absorbing media. Although this cooling can be accomplished by means of water injection, it can be more economically handled by the aspiration of secondary cooling air utilizing the high-velocity jet exhaust stream as an aspirator pump. However, accurate prediction and control of this secondary cooling air is absolutely necessary in the design of test cell and run-up silencing equipment. The structural limitations of the sound treatment and the self-generation of noise within the muffler or exhaust stack treatment depend on exhaust velocity; hence, the entire design of the silencing equipment is keyed to the accurate control of the secondary air. The majority of test cells are designed for much larger engines than are initially to be operated in the test cell; therefore, the secondary air augmenter must be capable of augmenting the prescribed amount of cooling air over a large range of engine sizes and operating conditions.

The aspiration of secondary air and the sound treatment itself must not affect the engine operation in any way. It must be designed so as not to affect adversely the thrust measurements by increasing tailpipe temperature through back pressure or excessive turbulence on the tailpipe. Thus, the design of the secondary air-augmenting system is an important factor in basic test cell design and the general design of run-up silencing equipment.

With this in mind, a study was begun of the variables affecting augmenter design by the engineering staffs of Trinity College and Industrial Sound Control, Inc. The literature was thoroughly surveyed, and a theoretical analysis of the problem was made. On the basis of this theoretical model study, an experimentation was begun as described herein. The results of the preliminary design studies were then applied to several full-scale installations, and the results of these installations were evaluated in the light of the design study predictions.

The independent variables considered or still under study are: the L/D ratio, the dimensionless ratio of α, λ, and β listed in the table of nomenclature, the effect of augmenter entrance geometry, and the effect of secondary and tertiary flow resistances. The data were correlated as to the effect of these variables on the dependent variable of secondary air aspiration ratio.

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Nomenclature

A = area, sq.ft.
γ = ratio of specific heats, C_p/C_v
L = length of section, ft. or in.
M = Mach Number
p = pressure, lbs. per sq.in.
P = pressure, lbs. per sq.in. absolute
R = gas constant
t = temperature, deg. F.
T = temperature, deg. absolute
v = velocity, ft. per sec.
W = rate of flow, lbs. per sec.
D = diameter, ft. or in.
ρ = density
F = thrust
g = gravitational constant

Dimensionless Ratios

$$\alpha = \frac{\text{area of diffuser exit}}{\text{area of mixing section}}$$

$$\lambda = \frac{\text{area of mixing section}}{\text{area of primary jet}} = \frac{AM}{AJ}$$

$$\mu = \frac{\text{secondary flow}}{\text{primary flow}}$$

$$\beta = \frac{\text{secondary density}}{\text{primary density}}$$

Subscripts

letters or numerals refer to points in drawings

Literature Review

A great many studies have been made of ejectors, jet pumps, and augmenters for the mixing of two fluid streams. The mixing of the fluid streams may take place at constant cross-sectional area or at constant pressure; by means of combining cones or augmenters; with various mixing lengths, with or without diffusers; and with many other variations. The literature on the mixing of fluid streams in a tube or duct is extensive.

Neumann and Lustwerk[1] and many others have shown that the mixing tube or muffler should have a value of L/D from 6 to 9 for good mixing. According to Flugel,[2] the tube should be a straight section. It is also true that the L/D ratio is influenced by the type of mixing process, increased thrust, and flow conditions in addition to the considerations of the earlier experiments. It was decided to use an L/D around 7 to 8 at the present so as to assure relatively good mixing.

Elrod[3] regarded it necessary to have a combining cone or augmenter for high-powered jet engines. Lindsey[4] considered the fact that the ratio of velocities greatly influences the extent of mixing that can take place, and Flugel had the same opinion. It was felt

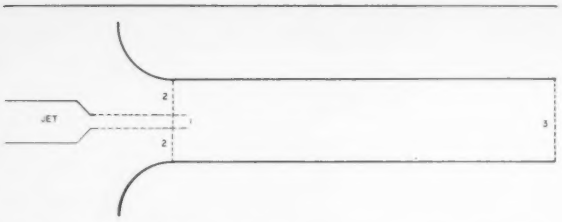

FIG. 1. Schematic layout of jet nozzle and augmenter system.

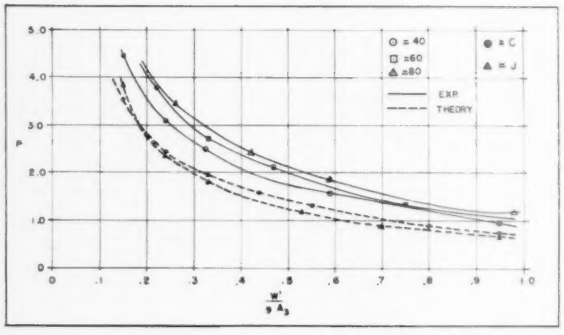

FIG. 2. Correlated results of experimental and theoretical augmenter design data.

that if air could be introduced at additional points to that of the original combining cone, the total air induced not only would be greater in amount but would produce more effective cooling. For this condition the term "tertiary air" has been used. This tertiary air may be controlled by ports rather than by an additional combining cone or augmenter. This is important not only from the mechanical and structural standpoint but also because it gives more latitude for variations in primary jet flow which is so important in test cell facility of design. Charyk[5] and others have shown by careful traverses that the so-called air stream does not always occupy completely the space available for secondary air and that boundary-layer effects and reverse currents may take place. In many runs of the experimental work this may account for some of the scattering of test results.

Keenan[6] shows considerable changes in induced flow with the changes in the primary or driving fluid nozzle position. It must be remembered that in large jet installations there would be substantial mechanical difficulties in changing jet positions once a test was set up. It is important to select an optimum position. Since afterburners may be used, room must be allowed for their use by adjustment in the thrust stand or in the augmenter, and possible sacrifice of optimum position may be necessary.

There seems to be no doubt that, if the diffuser angles are limited to 7° to 8°, an increased aspiration ratio will result. Since additional sound-reducing sections had been added after the mixing tube section it was decided that these sections acted to some extent as diffuser sections and at least did not reduce the aspiration ratio.

After a thorough study of the literature it was decided to investigate the basic problem theoretically, using a total momentum and thrust balance approach.

THEORETICAL STUDY

Keenan and Neumann[7] selected an optimum condition for an ejector system where they used a constant area mixing chamber and a rounded converging entrance or combining cone. Based upon the fundamental momentum equations, there resulted the following equation for complete mixing:

$$\left[1 - \frac{\lambda}{\lambda - 1} + \frac{1}{2}\left(\frac{\lambda}{\lambda - 1}\right)^2\right](\mu^2 + 2\mu + 1 - \lambda) = 0 \tag{1}$$

Consequently, if an aspiration ratio of 3 were desired, the ratio of the area of the muffler or mixing tube to that of the area of the jet comes out between 11 and 12. This ratio is generally compatible with test cell geometry and will be taken up again when discussing full-scale installations.

Engineering economy studies of jet-engine test cell use indicate aspiration ratios between $\mu = 0.75$ and $\mu = 8.0$ to be the ranges most used in test cell design.

A more rigorous method may be devised, according to Professor Charyk of Princeton University, whereby, starting with Fig. 1 and $m_3 = P_3 V_3 A_3$, there results

$$\frac{W_3}{gA_3} = \frac{\sqrt{\gamma}\, P_3 M_3}{\sqrt{R_3 T_3 g}} \sqrt{1 + \frac{\gamma - 1}{2} M_3^2} \tag{2}$$

and

$$\frac{W_1}{gA_3}(1 + \mu) = \frac{\sqrt{\tau}\, P_3 M_3}{\sqrt{R_3 T_3 g}} \sqrt{1 + \frac{\gamma - 1}{2} M_3^2} \tag{3}$$

For a great many cases P_3 will be atmospheric pressure and $R_1 T_1 = R_2 T_2 = R_3 T_3$. Assuming values of W_1/gA_3 and μ, a curve (No. 1) may be obtained with M_3 as ordinate and μ as abscissa. There results a series of straight lines of constant values of W_1/gA_3. Inserting proper values in formula similar to that of Eq. (2), it is possible to determine values of W_1/A_1 and W_2/A_2. Since

$$\frac{W_2}{gA_2} = \frac{\mu}{g}\left(\frac{W_1}{A_3}\right)\left[\frac{1}{1 - (A_1/A_3)}\right] \tag{4}$$

μ is obtained. Another curve (No. 2) may be plotted with M_2 as ordinate and μ as abscissa for constant lines of W_1/gA_3 values. This curve is for ease in picking off values of M_2 at certain μ values with any value of W_1/gA_3 assumed later. But $F_1 + F_2 = F_3$ where $F = Wv + pA = pA(1 + \gamma M^2)$ from which

$$Fg = \frac{w\sqrt{RTg}}{\sqrt{\gamma}} \frac{(1 + \gamma M^2)}{M\sqrt{1 + [(\gamma - 1)/2]M^2}} \tag{5}$$

and

$$(F_1 g/W_1) + (F_2 g/W_2) = F_3 g/W_3 \tag{6}$$

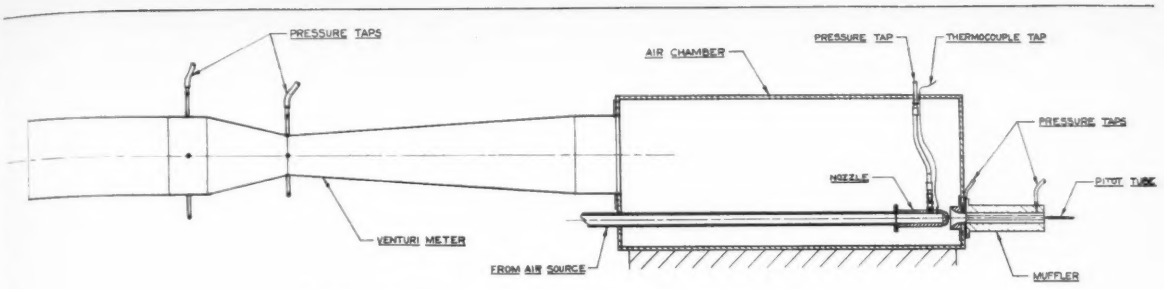

FIG. 3. Schematic section of experimental augmenter test setup.

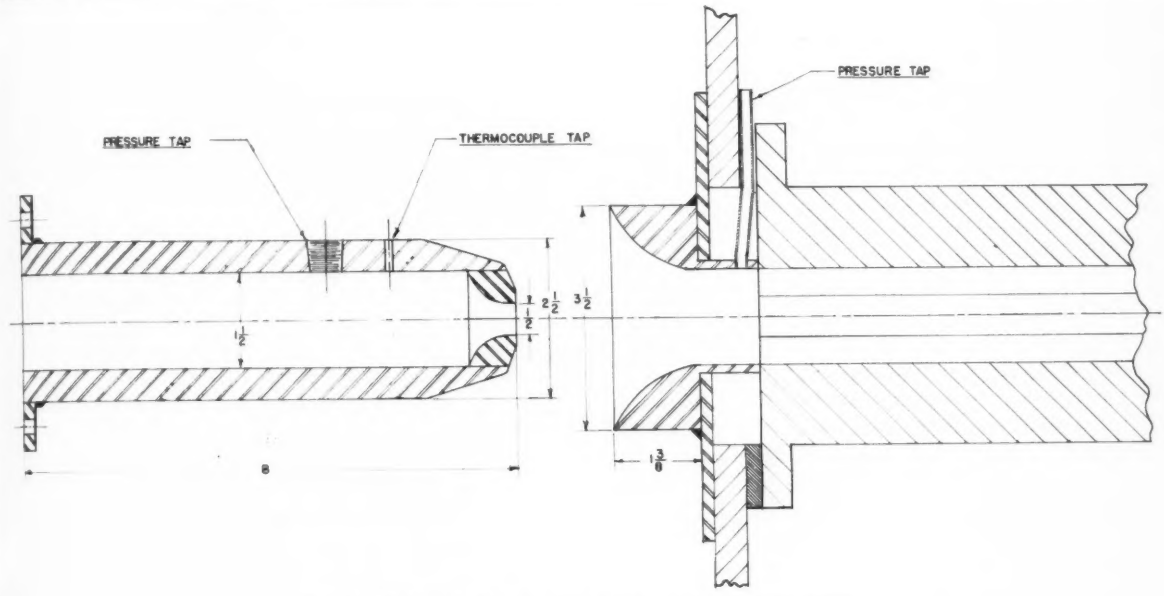

FIG. 4. Enlarged detail of nozzle and augmenter test system.

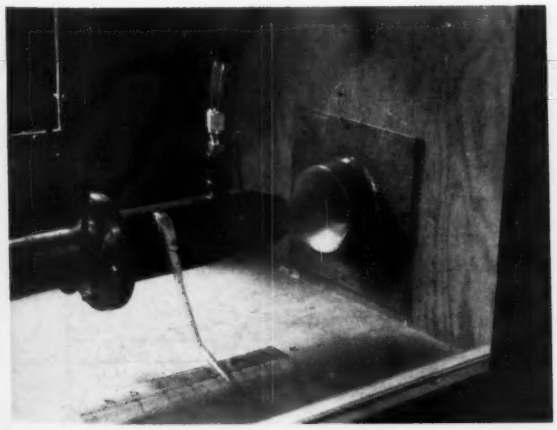

FIG. 5. Experimental augmenter testing system showing nozzle positioning indicator.

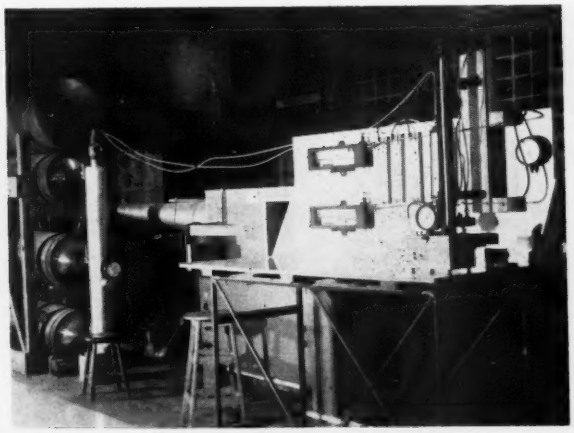

FIG. 6. Experimental augmenter testing setup.

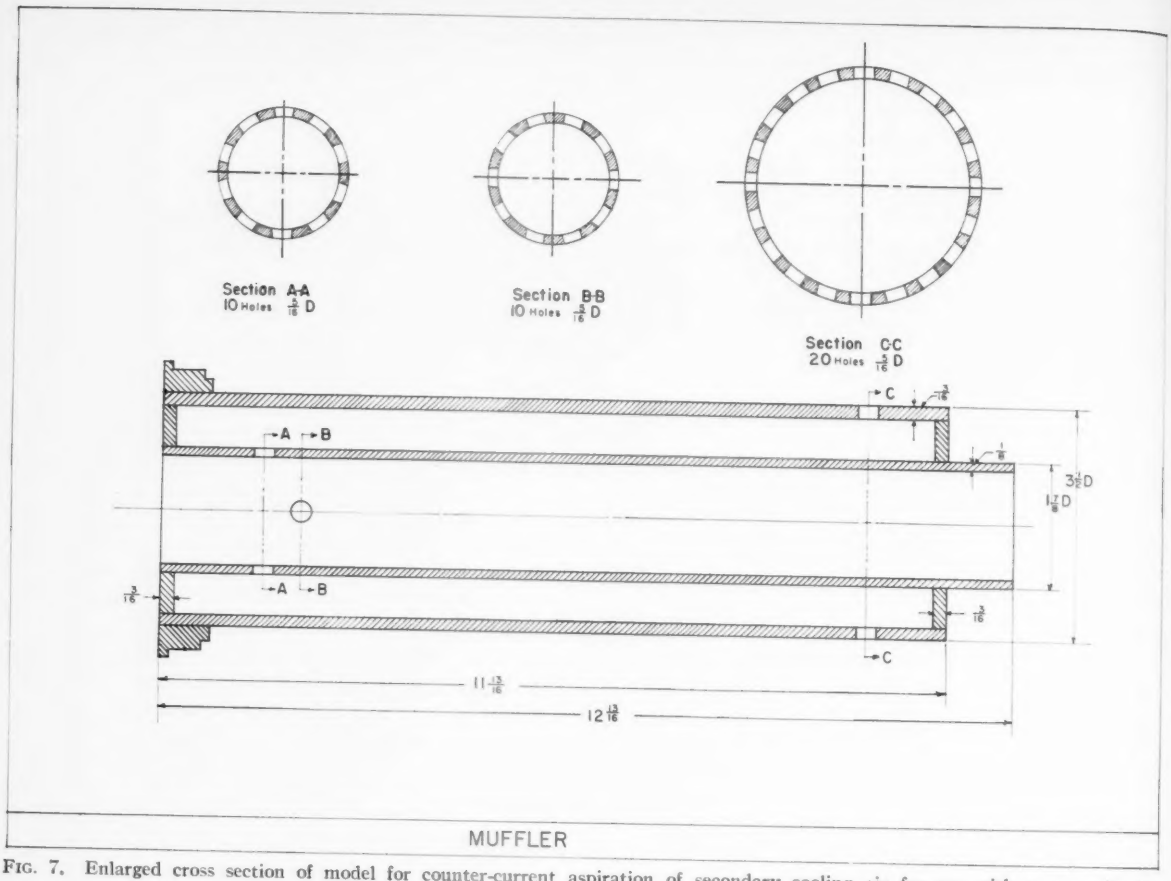

FIG. 7. Enlarged cross section of model for counter-current aspiration of secondary cooling air for use with run-up silencing equipment at The Glenn L. Martin Company, Baltimore.

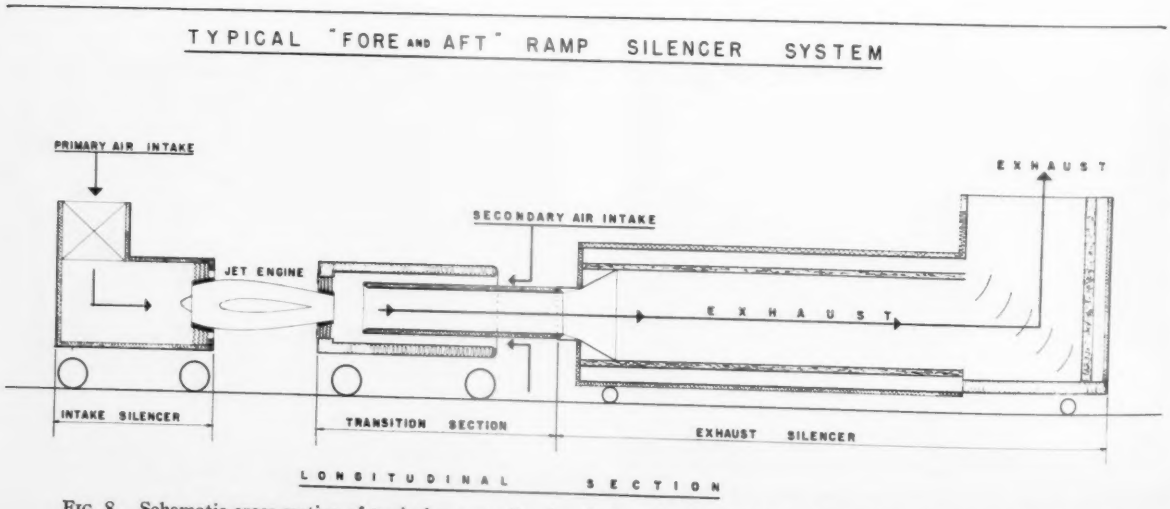

FIG. 8. Schematic cross section of typical run-up silencing devices showing position of secondary air augmenter system.

For any values of M_1, M_2, and μ it is possible to find F_3/W_3 and hence M_3. A curve (No. 3) may be plotted using the same coordinates as in curve (No. 1). The correct value of M_3 will be the intersection of constant W_1/gA_3 lines of curve (No. 1) with those of curve (No. 3). This procedure is repeated for different values of W_1/gA_3. This permits one eventually to plot lines of constant pressure with coordinates of μ and W_1/gA_3. The values marked C in Fig. 2 represent values obtained for jet pressure of 40 lbs. per sq.in. The details of these calculations and for a considerable range of pressures are expected to be incorporated in a later paper.

The method just outlined was abbreviated to the following: $F_2 = P_2A_2(1 + \gamma M_2^2)$ and, assuming M_2^2 to be very small or approaching zero, $P_0 = P_{32}$. Hence, $F_2 = P_0A_2$ and $F_3 = P_0A_2 + P_0A_1(1 + \gamma M_1^2)$; also

$$F_3 = A_3P_3(1 + \gamma M_3^2) \tag{7}$$

Since $P_0 = P_3$ or atmospheric pressure and P_{31}/P_0 is known, M_1 may be found. With A_3 of laboratory set-up known and F_3 calculated, the value of M_3 may be found from Eq. (7). From continuity:

$$W_1 + W_2 = W_3 = P_3A_3M_3\sqrt{\gamma g/R_3T_3} \tag{8}$$

Dividing through by W_1:

$$1 + \mu = P_3(A_3/W_1)M_3\sqrt{\gamma g/R_3T_3} \tag{9}$$

The value W_1/A_3 may be assumed and values of μ calculated from Eq. (9). Since a number of assumptions were made, all on the safe side, a pessimistic value of μ results. Values for 40 lbs. per sq.in. are shown in Fig. 2 and marked J.

By means of these curves, design data may be found. For example, if the jet pressure drop were 40 lbs. per sq.in., and an aspiration ratio of 3 were desired, there results from Fig. 2 a value for W_1/gA_3 of 0.22. Since W_1 and g are known, A_3 may be determined and hence the diameter of the mixing section or muffler. With a value of L/D of 8.0, the value of L may be determined and the mixing tube designed.

In the case of the second type of muffler as shown in Fig. 7, no particular formula was worked out. Consideration was given to the loss of pressure in the long travel of the secondary air. However, the design was based mostly on the experimental model used in the laboratory.

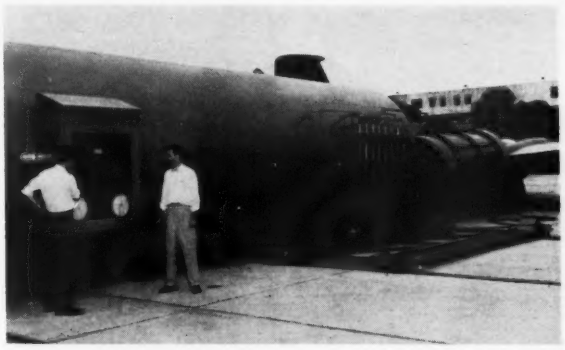

FIG. 9. Aircraft run-up exhaust silencing system showing full-scale secondary air augmenter in position at The Glenn L. Martin Company, Baltimore.

EXPERIMENTAL PROCEDURE AND EQUIPMENT

The test apparatus was arranged as shown in Figs. 3 and 4. Air is supplied by a two-stage compressor to a series of tanks. All the tanks are connected to a manifold equipped with a safety blowoff valve. A main control valve, manually operated, allows controlled pressures to be maintained at the entrance to the primary nozzle. This pressure was measured by a Heise gage, which had been previously calibrated. A thermocouple was maintained near entrance to the nozzle proper so that nozzle conditions could be better known. A long pipe between the manifold and the nozzle was used to smooth out any fluctuations of flow. Each nozzle section was provided with a feeder tube, which changed the section of the main line to the section of the nozzle very gradually thus reducing losses and preventing any irregular flow. The secondary air entered a calibrated Venturi meter section, with flared entrance to reduce losses. After the secondary air passed through the Venturi section it entered a large chamber resembling a test cell chamber. The Venturi section had a flexible connection so that the test chamber could be moved in order to place the jet at different positions with respect to the augmenter entrance. Fig. 5 shows the details for changing the nozzles when desired by means of a port in the test chamber walls. There were four sizes of nozzles used: $^1/_2$-, $^1/_4$-, $^3/_8$-, and $^1/_8$-in. inside diameters. Two sizes of wooden mufflers were used, each being octagonal in shape to conform to Industrial Sound Control muffler design. A third muffler used was made from steel pipe and hence

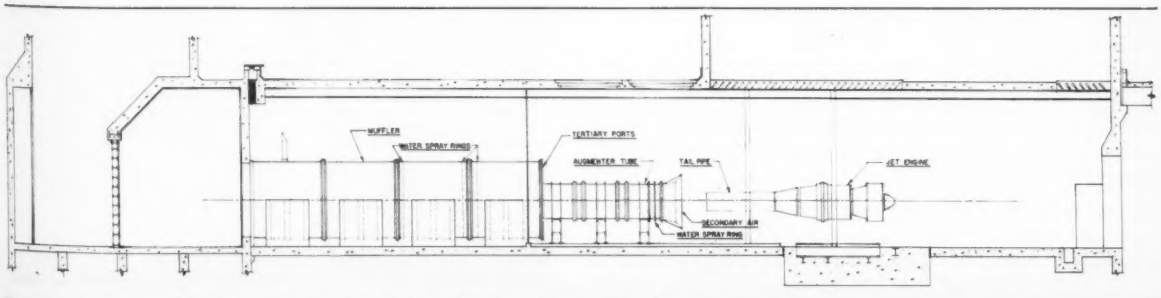

FIG. 10. A cross-section schematic drawing of full-scale secondary and tertiary augmenter system in operation at A. V. Roe Canada Limited, Toronto, Ontario.

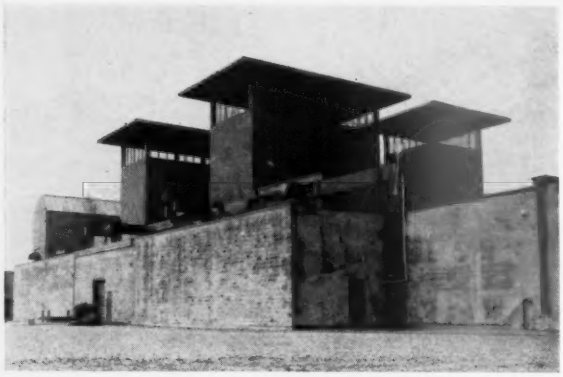

FIG. 11. External view of the test cells at A. V. Roe Canada Limited in which the secondary and tertiary augmentation system is in operation.

was circular in shape. Pressure taps, together with a number of thermocouples, were inserted at a number of points, as indicated in the figures. Each thermocouple lead was brought out to a switch point so that the same L & N potentiometer could be used. The photograph shown in Fig. 6 illustrates the general arrangement of the main test panel. Merriam gages were used most frequently, although in some instances ordinary U-tube manometers were used. At the exit of the mufflers, an arrangement was made to obtain an exit velocity traverse. The pickup was made by means of a hypodermic needle connected by copper tubing to the gage on the main panel. A machine head was used so that the distances between traverse points could be quite accurately determined. This gave a good traverse picture, and the probe did not influence the flow to any great extent. The setup was such as to enable variation of nozzle size, pressure at the nozzle, distance of nozzle from the augmenter, area available for the secondary air, and three different diameters of mufflers. It was felt unnecessary to vary the length of the mufflers since L/D factors are fairly well explored and reported in the literature.

After a number of test flows it was felt that the Venturi meter was not always as accurate and sensitive as needed but served as an overall, approximate check. The nozzles were then calibrated and the induced flow calculated by the difference between total exit flow and nozzle flow.

Further experiments are being conducted in the Hallden Engineering Laboratory to study the effect of the resistance offered to the secondary flow on the aspiration ratio.

The second type of augmenter and mixing tube was built for laboratory tests (see Fig. 7). This was a proposed model of the contemplated design for an aircraft run-up silencer. The system acted as a connection piece between the silencer and the aircraft and augmented secondary air into the exhaust stream for purposes of cooling. The design required the silencing structure to be of minimum size for portability considerations; hence, the secondary cooling air had to be kept at a minimum. A minimum quantity of secondary cooling air had to be aspirated at the connection point between the engine tailpipe and the silencing structure in order to prevent excessive back pressure and engine tailpipe overheating. Since the augmenter system is effectively pumping air from atmospheric pressure to atmospheric pressure through the medium of the high-velocity jet stream, the engine will not feel any of the back pressure in the exhaust silencing equipment if a minimum amount of cooling air is aspirated at the tailpipe entrance to the silencing equipment. If the augmenter is not choked and the minimum secondary cooling air can be aspirated, the engine feels only the pressure drop in the secondary air silencing system. This system was to be operative over a twofold range in thrust and necessitated a minimum aspiration ratio of $\mu = 1.2$ for the smaller existing engine and $\mu = 0.5$ for the larger future engine.

On the basis of theoretical considerations and the laboratory tests of this model, a full-scale silencing system was designed and built for The Glenn L. Martin Company for operation with the B-57 aircraft. (See Figs. 8 and 9.) Data taken by the Martin Company after the installation was completed indicate that the design aspiration ratio was reached within plus or minus 5 per cent and that the effect on the engine was negligible. The engine did not know whether the muffler and silencing system were attached or not.

Results of several hundred experimental runs are herein reported. A number of complex correlations have been made to aid in studying certain factors in the augmenter performance; however, presentation of these data in a form most useful for engineering design of augmenters is shown in the figures. The results of all the experimentation have been correlated in terms of the aspiration ratio μ and the ratio W_1/gA_3.

FULL-SCALE INSTALLATION

The general layout of a full-scale installation at A. V. Roe Canada Limited, Toronto, is shown in Fig. 10. The jet exhausts to bell-shaped augmenter tube, then through an octagonal-shaped muffler, to sound treatment, and finally to exhaust stack.

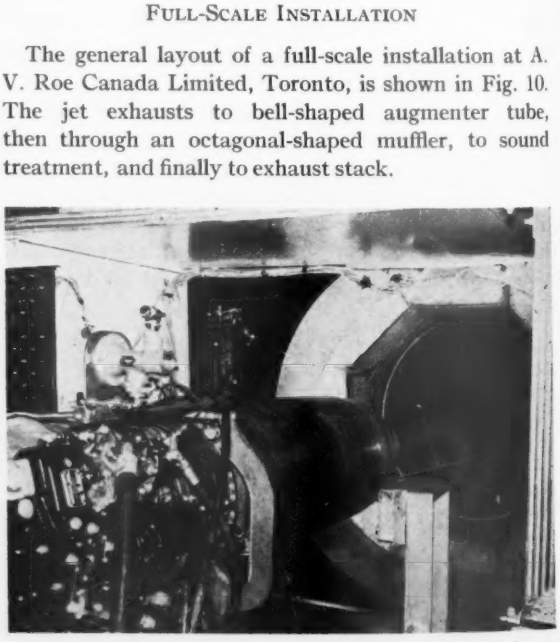

FIG. 12. Typical jet-engine exhaust tailpipe position relative to a secondary air augmenter muffler system.

The augmenter system in this installation was designed on the basis of preliminary theoretical studies and later confirmed by model studies. The design requirement called for an exit gas temperature of 450° after cooling, with an exit velocity of 250 ft. per sec. These conditions were to hold over a 400 per cent variation in thrust range, utilizing any existing smaller engine and similarly utilizing the test cell and system for a contemplated larger engine. It soon became evident that upon initial consideration of the problem a single augmenting system sufficient for the small existing engine would not aspirate enough air for the larger contemplated engine; similarly, an augmenter designed for the larger future engine would augment too much air when operating with the smaller existing engine because of the difference in tailpipe diameters. For this reason, an adjustable tertiary augmenter system was devised, consisting of 24 holes, each $2^3/_4$ in. in diameter.

When the test cell is operating with the smaller engine, approximately 80 per cent of the required secondary air is augmented through the first bell mouth, and about 20 per cent of the required air is augmented through the adjustable tertiary ports. When operating with larger engines having large-diameter tailpipes, the percentage of augmented air coming through the tertiary ports increases, as the augmented air through the secondary bell mouth decreases with increasing tailpipe diameter. The required secondary air aspiration ratio, μ, consistent with the previously stated exit design requirements, ranged from $\mu = 3.5$ for the smaller engine to $\mu = 2.5$ for the larger engine.

Tests were made at this installation after construction. The observations were made of the temperature at the grill work at the rear of the diffusion chamber near the base of the exhaust stack. Results of temperature and velocity measurements at the full-scale installation by the A. V. Roe Canada Limited personnel indicated an operating aspiration ratio of $\mu = 3.13$ for a calculated predicted μ under these same operating conditions—i.e., tertiary port opening—of 3.00. It is felt that this is well within the accuracy of calculation for the tertiary control ports. At the time of the tests, the tertiary ports were set at 94 per cent of the maximum adjustable opening, and the water rings installed were not used. With afterburner operating, it will be necessary to use water rings for additional cooling effect.

Fig. 11 is an external view of the test cells at A. V. Roe. In Fig. 12 is shown a close-up view of typical Industrial Sound Control octagonal mufflers with augmenter and supplementary water rings.

Conclusions

The importance of secondary air cooling in test cell and run-up silencing design requires careful augmenter design to ensure proper operation of both the jet engine and the silencing equipment. The simplified calculations and the rigorous calculation herein presented will both give conservative estimates of the secondary air ratio, μ. The corrected theoretical prediction and models data herein presented have been proved in the design of full-scale installations. The theoretical calculations and model data may be used in the design of secondary air augmenters quite satisfactorily; however, further investigations and refinement of the effect of the other independent variables might well be worth while, and these studies are in progress.

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Synthetic Fabric-Acrylic Resin Impregnates for Aircraft Canopy Edge Attachments

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SUMMARY

Impregnates made from acrylic resin and various synthetic fabrics have been evaluated for general physical properties and especially for those characteristics pertinent to their use as aircraft canopy edge attachments. A description is given of the effect of the type and construction of the reinforcing fabric on impregnate physical properties, and a comparison is made with properties of an acrylic-glass fabric impregnate of a type in current use. Synthetic fabric impregnates are more suitable for the canopy edge attachment application since these impregnates have a thermal expansion coefficient more nearly equal to cast acrylic plastic than the glass fabric impregnates. Therefore, thermally induced stresses in the adhesive bond between the canopy and edge attachment are largely eliminated. Strength properties of synthetic fabric impregnates are adequate for the edge attachment application but, in general, are not equal to those of glass fabric impregnates. Synthetic fabrics have strength and moduli characteristics nearly equal to those of the resin and thus do not supply much reinforcement for the resin, but they do act to reduce resin notch sensitivity. The mechanism of impregnate failure is discussed briefly, and methods of increasing strength properties by hot-stretching impregnates are described. It is concluded that synthetic fabric impregnates should be entirely suitable for canopy attachment applications when properly designed and that the best synthetic fiber for this application is Orlon.

INTRODUCTION

INCREASING PERFORMANCE DEMANDS on aircraft have created a need for improved methods of attachment of transparent acrylic canopies. The conventional means of attachment of monolithic acrylic canopies have been to cement a strip of acrylic resin reinforced with glass fabric or wire mesh to the edge of the canopy and then to bolt this edging to the plane. Glass fabric and wire mesh have been found to impart high strength to acrylic impregnates. However, these materials are not well suited for this application because the wide temperature changes encountered in aircraft operation cause large thermally induced stresses in the cemented joints between the canopy and edge attachment owing to differences in the coefficient of thermal expansion of the acrylic resin canopy and the glass- or wire-reinforced acrylic edge attachments. These stresses may cause crazing near the edge of the canopy or failure in the cemented bond with the resultant separation of the canopy from the attachment. More recently, edge attachments reinforced with synthetic fabrics have been used with the object of matching more closely the thermal expansion coefficient of cast acrylic resin and thereby reducing the thermal stresses leading to these faults.

This investigation was undertaken to determine the characteristics of impregnates made with synthetic fabrics so that improved designs for the attachment of Plexiglas canopies might be developed. For this purpose impregnates were constructed from a variety of synthetic fabrics selected from the standpoint of strength characteristics and weather resistance in order to determine the influence of the fabric on impregnate properties and to define more exactly the characteristics of these impregnates. The results obtained should also be of general interest in applications other than canopy attachments in indicating the type of properties that may be obtained with synthetic fabric reinforcements.

EXPERIMENTAL METHODS

The fabrics used in this investigation are described in detail in Table 1. All fabrics were received as greige goods and were scoured prior to use in a 0.1 per cent aqueous solution of Triton X-100 at 65°C. and then dried and cut into sections. The number of plies of each fabric in the $^1/_8$-in. thick impregnate that was prepared was chosen so that the total thickness of the plies prior to impregnation was approximately equal to the total thickness of plies, also prior to impregnation, of a $^1/_8$-in. thick standard impregnate made from No. 128 glass cloth.

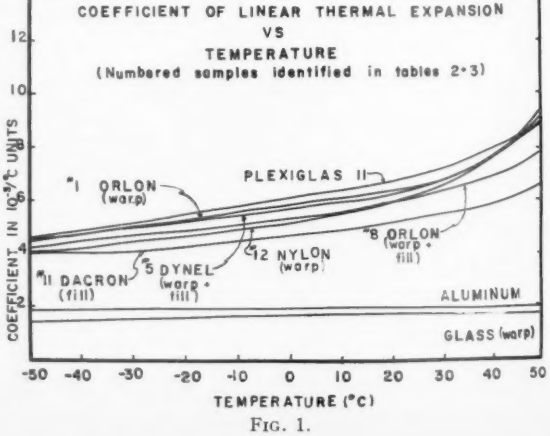

FIG. 1.

* The authors' appreciation is extended to Wellington Sears Company, Burlington Mills Corporation, and Martin Weiner Company for assistance in the selection of synthetic fabrics for this investigation. The Wellington Sears Company was also extremely helpful in supplying small quantities of experimentally prepared fabrics for study of the effect of cloth construction variables. The help of Rohm & Haas Company laboratory personnel in determining the physical property data included in this report is gratefully acknowledged.

The impregnates were prepared in the laboratory by a procedure that approximated the conventional casting technique now used in commercial production. This procedure consisted of impregnating the fabric with a methyl methacrylate monomer-polymer mixture (5:1 weight ratio) catalyzed with benzoyl peroxide. The impregnate was cast between cellophane liners supported by glass plates and given a cure of 20 hours at 60°C. followed by 1 hour at 120°C. Under these conditions the residual monomer content of the impregnates was kept under 1 per cent by weight. The individual fabric plies in all impregnates were kept parallel in respect to the warp direction. All impregnates had nominal dimensions of $^1/_8$ by 12 by 18 in.

The impregnates were cut into appropriate sections for the various tests with the long axis of specimens for strength determinations cut parallel to the fill threads of the fabric. This was done because aircraft canopy edge attachments made from impregnates would normally be longer than the width of a roll of fabric. Thus, to eliminate joints, edgings would be made with their lengthwise direction parallel to the warp direction of the fabric. Consequently, working stresses would normally be applied perpendicular to the lengthwise direction of the edge attachment or parallel to the fill direction of the reinforcing fabric.

Results

Bearing, tensile, flexural, and impact strength tests were determined according to American Society for Testing Materials procedures D-953-48T, D-638-49T, D-790-49T, and D-265-47T, respectively, except that a 0.186-in. diameter pin was used in a 0.187-in. diameter hole for the bearing strength tests to conform to the bolt or rivet diameter currently in use for edge attachments on aircraft. Flexural values were determined in a flatwise position. Strength values were calculated according to the pertinent ASTM procedures, and values for the arithmetic means of—generally—five observations are included, together with the value of the standard deviation from this mean.

The thermal coefficient of linear expansion of the impregnates was determined on $^1/_2$ to 1 in. by 10-in. long specimens parallel and perpendicular to the warp threads of the cloth. Specimens were preconditioned for not less than 48 hours at 23°C. and 50 per cent relative humidity. These determinations were made on specially designed equipment capable of recording the change in length of the specimen and the temperature to the nearest 0.0001 in. and $^1/_2$°C., respectively. The thermal coefficient of linear expansion was determined at various temperatures by measuring the slope of the recorded length vs. temperature curve. Fig. 1 describes the linear thermal expansion coefficients of some of the impregnates measured both parallel and perpendicular to the warp direction of the reinforcing fabrics and over the temperature range from −50°C. to +50°C.

Results of the various physical tests are summarized in Tables 2 and 3. Other values determined after 1

Table 1

Characteristics of Synthetic Fabrics Used to Make Impregnates

Fabric Style No.	Chemical Type	Manufacturer	Thread Count	Wt. Oz./Yd.²	Type of Thread† and Weave	Tensile Strength, (Lbs.)‡ Warp	Fill
3970	Orlon	Martin Weiner Co.	80 × 42	4.54	Open weave (F)	122 (S)	153
3168	Orlon	Martin Weiner Co.	68 × 67	1.69	Tight weave (F)	70 (S)	73
MS33	Orlon	Wellington Sears Co.	88 × 88	6.05	Medium weave (F)	155 (S)	155
MS121*	Orlon	Wellington Sears Co.	76 × 36	5.81	Open weave (F) warp (S) fill	128 (S)	80
MS145*	Orlon	Wellington Sears Co.	80 × 36	6.81	Open weave (F)	109 (S)	241
MS147*	Orlon	Wellington Sears Co.	80 × 44	6.55	Open weave (F) warp (S) fill	111 (S)	102
1220	Orlon	Wellington Sears Co.	37 × 37	6.75	Tight weave (S)	111 (S)	124
3512	Orlon	Burlington Mills Corp.	56 × 58	6.00	Open weave (F)	202 (G)	212
MS122*	Orlon & Dacron	Wellington Sears Co.	76 × 46	5.03	Open weave (F) Orlon warp (S) Dacron fill	104 (S)	115
MS94*	Orlon & Nylon	Wellington Sears Co.	80 × 32	6.27	Open weave (F) Orlon warp (S) Nylon fill	138 (S)	145
MS144*	Orlon & Nylon	Wellington Sears Co.	80 × 32	6.42	Open weave (F) Orlon warp (F) Nylon fill	125 (S)	385
MS146*	Orlon & Nylon	Wellington Sears Co.	80 × 40	6.75	Open weave (F) Orlon warp (S) Nylon fill	141 (S)	166
SN5	Nylon	Wellington Sears Co.	58 × 58	18.30	Tight weave (F)	1,169 (G)	1,177
SN19	Nylon	Wellington Sears Co.	37 × 37	6.75	Tight weave (S)	200 (S)	200
SN41	Nylon	Wellington Sears Co.	20 × 20	12.50	Tight weave (S)	495 (S)	494
SN49	Nylon	Wellington Sears Co.	40 × 40	2.30	Tight weave (F)	165 (G)	155
22060	Dynel	Burlington Mills Corp.	40 × 30	9.60	Tight weave (S)	263 (G)	230
23668	Dynel	Burlington Mills Corp.	43 × 40	6.00	Tight weave (S)	167 (G)	134
3513	Dacron	Burlington Mills Corp.	51 × 52	6.60	Open weave (F)	300 (G)	300
128-114	Glass	Owens-Corning Fiberglas Corp.	42 × 32	6.00	Medium weave (F)	250 (S)	200

The properties of impregnates made from the following fabrics are not described since no unusual or outstanding results were obtained:

Orlon No. 39000 (of Martin Weiner Co.); MS34A, SO14, SO15, 11003 (of Wellington Sears Co.); 21709, 3193, 22621, 21667 (of Burlington Mills Corp.).

Nylon No. 5894, 6654 (of Martin Weiner Co.).

Dacron No. 1002 (of Martin Weiner Co.); FV1140, FV1101 (of Wellington Sears Co.); 21174, 9519 (of Burlington Mills Corp.).

Glass No. 143-114 (of Owens-Corning Fiberglas Corp.).

* Experimental fabrics especially prepared by Wellington Sears Co.

† (F) Indicates continuous filament thread, (S) indicates spun staple fiber thread.

‡ (S) Refers to strip test, (G) grab test.

TABLE 2

Properties of Synthetic Fabric-Acrylic Impregnates

(The Average of Five Specimens Conditioned a Minimum of 48 Hours at 23°C. 50% Relative Humidity Prior to Testing)

Sample No.	Fabric No.*	No. of Plies	Resin Content by Wt., %	Bearing Strength: Bearing strength, psi	Bearing Strength: Max. bearing stress, psi	Bearing Strength: Elongation at max. stress, in.	Tensile Strength: Max. tensile stress, psi	Tensile Strength: Modulus of elasticity, psi	Tensile Strength: Elongation at max. stress, %
1	3970–O	8 (F)†	71	7,890	20,900	0.032	6,910	560,000	2.5
2	3168–O	25 (F)	66	8,960	22,500	0.033	7,280	504,000	4.4
3	MS33–O	10 (F)	62	9,130	24,500	0.055	7,420	552,000	4.0
4	SN49–N	18 (F)	69	7,330	26,700	0.105	16,300	404,000	20.9
5	22060–DY	5 (S)	60	8,060	16,200	0.020	6,020	490,000	1.7
6	128–114–G	16 (F)	48	25,800	47,100	0.034	32,500	2,252,000	1.8

Sample No	Flexural Strength: Max. flexural stress, psi	Flexural Strength: Modulus of elasticity, psi	Flexural Strength: Deflection at max. stress, in.	Charpy Type Impact Strength: Notched, ft.lbs. per in. of notch	Charpy Type Impact Strength: Unnotched, ft.lbs. per in. of width
1	12,000	515,000	0.190	3.2	9.8
2	15,300	516,000	0.390	3.6	6.6
3	15,300	609,000	0.330	5.4	20.3
4	11,500	414,000	0.350	13.4	27.4
5	10,400	508,000	0.100	1.9	2.2
6	39,400	1,453,000	0.130	10.0	19.1

* Letters after fabric No. indicate fiber type: O = Orlon; N = Nylon; D = Dacron; DY = Dynel; G = Glass.
† (F) and (S) refer to filament or staple fiber fill thread.

NOTES

(1) The coefficient of variation, defined as the standard deviation of the mean divided by the mean, of all these data is not over 10% with the following exceptions:
  (a) Bearing strength of Samples No. 5 and No. 6 = 12%.
  (b) Flexural modulus of elasticity of Samples No. 2 and No. 3 = 11%; of Sample No. 4 = 15%.
  (c) Unnotched impact strength of Sample No. 1 = 13%.
  (d) Seven elongation or deflection measurements—undoubtedly due to difficulties of measuring small dimensional changes.
(2) Flexural tests were made flatwise.
(3) Impact tests were made edgewise on composite specimens stacked to equal approximately $\frac{1}{2}$ in. × $\frac{1}{2}$ in. in cross section.
(4) Ultimate bearing failure occurred in all cases as a tensile rupture across the bearing pin hole.

year's outdoor exposure at Bristol, Pa., or after a 48-hour immersion in water at 50°C. are not included in the table since properties were, in general, unaffected by these exposure conditions, with the exception of samples made with nylon fabric.

Discussion of Results

The results described in Fig. 1 illustrate the fact that the linear thermal expansion coefficients of synthetic fabric impregnates closely approximated those of Plexiglas II over the entire temperature range, whereas the glass fabric impregnate had much lower coefficients over the same range. This observation was true of all synthetic fabric impregnates investigated and was not a function of fabric construction.

The strength properties of the synthetic fabric impregnates were generally much lower than those of the glass fabric impregnate. This behavior was expected since the synthetic fibers have strengths and moduli of the same order of magnitude as the resin and hence cannot effectively reinforce the plastic. Because of this, the ultimate strength values reported here are of the same order as those of Plexiglas II. Only in cases where the tensile strength of the fiber was appreciably greater than that of the plastic—such as with the nylon fabrics used in this work—was the ultimate strength of the impregnate greater than that of unfilled plastic, although, with these nylon impregnates, the resin encasing the fabric cracked prior to reaching the ultimate stress because of its higher modulus. With other types of synthetic fabric, and with nylon types prior to resin cracking, the fiber merely acted as filler and did not support much of the applied load. This behavior is illustrated in Table 4, which shows that, in general, the tensile breaking loads of the impregnate were less than the breaking load of the fabric present. This was not the case with glass fiber because, with its inherent stiffness and high modulus, the fiber strands supported the applied load and minimized the stress on the resin.

Conversely, many cloths increased the impact strength over that of the base resin. In this respect, the synthetic fabric did act as a reinforcing agent and tended to reduce the notch sensitivity of the plastic, as indicated by the ratio of notched and unnotched impact strength. Thus, an impregnate should not fail by brittle fracture of the resin which might occur under all types of stress with no fabric present. The impact strength of some nylon-reinforced samples surpassed that of the glass-reinforced sample. This is attributed to the high strength and extensibility of the nylon fiber which permits it to absorb energy from the impact blow.

In general, properties of the impregnates reflected the properties of the type of fiber from which they were constructed. Thus, samples made with nylon fabric had the highest ultimate tensile strength, lowest moduli, and greatest elongation under load in accordance with

the high tensile and extensibility characteristics of nylon fiber. Impact strengths with nylon samples were also high, as described above. Similarly, the nylon impregnates were more adversely affected by outdoor exposure than those made from other fabrics, again in accordance with the known relatively poor resistance of nylon to weathering.

The impregnate made with Dacron had properties that were generally intermediate between those of impregnates made with nylon and Orlon, as would be expected from the fiber properties. Dacron fabrics were not investigated more extensively since, at the time this work was carried out, the fiber was being modified by the du Pont Company in the direction of lower tensile strength and greater extensibility, both characteristics that seemed undesirable for this application.

Impregnates made from the Dynel fabrics had no outstanding characteristics, but the fabrics evaluated were made from staple fiber threads rather than continuous filament threads. It is possible that chemical action of the impregnating resin on Dynel fibers may have occurred and thus weakened the fabric.

Orlon fabric impregnates showed the best weathering properties, as was expected from Orlon fiber characteristics. These impregnates had no outstanding properties, but there were also no deficiencies. Impregnate physical properties were unaffected by heat-setting the Orlon fabric.

TABLE 3

Properties of Synthetic Fabric-Acrylic Impregnates

(The Average of Five Specimens Conditioned a Minimum of 48 Hours at 23°C. 50% Relative Humidity Prior to Testing)

				Bearing Strength			Tensile Strength		
Sample No.	Fabric No.*	No. of Plies	Resin Content by Wt., %	Bearing strength, psi	Max. bearing stress, psi	Elongation at max. stress, in.	Max. tensile stress, psi	Modulus of elasticity, psi	Elongation at max. stress, %
7	1220–O	5 (S)†	71	9,780	19,900	0.025	5,490	551,000	3.4
8	1220–O	6 (S)	67	10,200	19,900	0.022	6,050	573,000	2.4
9	1220–O	7 (S)	59	9,780	21,300	0.034	5,330	557,000	7.9
10	3512–O	8 (F)	65	8,810	21,900	0.034	5,680	548,000	7.2
11	3513–D	8 (F)	65	7,940	24,000	0.129	8,800	555,000	23.7
12	SN5–N	3 (F)	53	5,310	31,100	0.200	14,100	387,000	24.9
13	SN19–N	7 (S)	63	7,220	22,100	0.123	7,030	375,000	10
14	SN41–N	4 (S)	64	7,320	20,900	0.156	6,500	356,000	34
15	23668–DY	7 (S)	66	8,570	17,600	0.023	6,960	450,000	2.1
16	MS–121–O	7 (S)	71	8,320	19,700	0.028	5,940	514,000	5.2
17	MS–145–O	7 (S)	66	10,700	26,500	0.059	7,860	617,000	9.1
18	MS–147–O	6 (S)	72	9,730	20,800	0.028	6,320	535,000	2.7
19	MS–122–OD	7 (S)	71	8,150	23,500	0.047	5,880	465,000	11.7
20	MS–94–ON	7 (S)	65	7,340	22,500	0.046	5,610	397,000	12.9
21	MS–144–ON	7 (F)	67	8,490	29,800	0.220	14,000	472,000	22.0
22	MS–146–ON	6 (S)	68	8,040	23,200	0.106	7,030	406,000	10
23	Plexiglas II	...	...	9,190	33,000	0.079	9,000	425,000	4.0

	Flexural Strength			Charpy Type Impact Strength	
Sample No.	Max. flexural stress, psi	Modulus of elasticity, psi	Deflection at max. stress, in.	Notched, ft.lbs. per in. of notch	Unnotched, ft.lbs. per in. of width
7	11,300	522,000	0.204	...	...
8	11,500	535,000	0.146	...	...
9	11,900	531,000	0.314	...	...
10	13,700	571,000	0.212	6.3	...
11	14,800	530,000	0.387	14.5	...
12	12,500	451,000	0.404	30.7	...
13	11,300	373,000	0.423	...	...
14	10,700	365,000	0.408	...	...
15	11,400	509,000	0.112	1.7	...
16	12,700	532,000	0.159	2.0	...
17	15,900	596,000	0.316	8.0	25.5
18	12,900	500,000	0.213	2.8	6.5
19	14,000	529,000	0.343	3.5	...
20	12,800	444,000	0.336	2.9	...
21	13,700	452,000	0.505	...	...
22	11,700	413,000	0.408	...	...
23	17,400	690,000	0.374	0.6	6.7

* Letters after fabric No. indicate fiber type: O = Orlon; N = Nylon; D = Dacron; DY = Dynel; G = Glass.
† (F) and (S) refer to filament or staple fiber fill thread.

NOTES

(1) The coefficient of variation, defined as the standard deviation of the mean divided by the mean, of all these data is not over 10% with the following exceptions:
(a) Bearing strength of Sample No. 20 = 12%.
(b) Maximum tensile stress of Sample No. 7 = 13%; of Sample No. 18 = 12%.
(c) Fourteen elongation or deflection measurements—undoubtedly due to difficulties of measuring small dimensional changes.
(2) Flexural tests were made flatwise.
(3) Impact tests were made edgewise on composite specimens stacked to equal approximately $\frac{1}{2}$ in. × $\frac{1}{2}$ in. in cross section.
(4) Ultimate bearing failure occurred in all cases as a tensile rupture across the bearing pin hole.

TABLE 4

Comparison of Impregnate and Fabric Tensile Strength

Sample No.	Cloth No.	Resin Content by Vol., %	No. of Plies	Impregnate Tensile Strength, Psi	Elongation at Max. Stress, %	Cloth Fill* Strength, Lbs.	Breaking Load of Cloth, Lbs.	Breaking Load of 1/8 × 1 In. Impregnate, Lbs.
1	3970 Orlon	71	8	6,910	2.5	153	1,220	865
3	MS33 Orlon	62	10	7,420	4.0	155	1,550	928
10	3512 Orlon	65	8	5,680	7.2	212	1,695	710
12	SN5 Nylon	50	3	14,100	24.9	1,177	3,520	1,762
4	SN49 Nylon	69	18	16,300	20.9	155	2,790	2,035
11	3513 Dacron	65	8	8,800	23.7	300	2,400	1,100
5	22060 Dynel	60	5	6,020	1.7	230	1,150	752
6	128 Glass	48	16	32,500	1.8	200†	3,200	4,060

* Values may have been determined by strip or grab method. See Table 1.
† Designated as minimum value by manufacturer.

The type of weave in fabrics used in making impregnates was also found to have an effect on impregnate properties. However, an impregnate made with an open-mesh fabric would necessarily have a higher resin content, and this generally reduces other physical properties. The weight of the synthetic fabric appeared to have little effect on impregnate properties. (Compare Sample No. 13 with No. 14 and Sample No. 3 with No. 17.)

Impregnates made with cloth constructed from continuous filament thread had greater mechanical strength properties than similar impregnates made with fabrics having staple fiber threads, as shown by a comparison of Samples Nos. 16 and 17 and also Nos. 20 and 21. This was especially true in the case of impact strength.

Although the general lack of reinforcement of acrylic impregnates by synthetic fabrics can be attributed directly to the tensile and moduli characteristics of the fibers, it was believed that impregnate properties might be improved by stretching the fabric slightly so that the threads might more effectively support the resin. Because of a lack of stiffness compared to glass fibers, synthetic fibers in an impregnate made under low pressure would probably be in a relaxed state for the most part and could not all be loaded until the resin around them had failed. (Compare results listed in Table 4.)

In order to examine this possibility, strips of impregnate were heated for 5 to 10 min. at 150° C. and then stretched to an elongation of 5 to 10 per cent. Elongations of over 10 per cent resulted in rupture. The samples were then allowed to cool to room temperature in the stretched position. No shrinkage was observed after several days at room temperature, and the fibers were assumed to be held under slight tension by the encasing resin.

The properties of impregnates elongated in the above manner are listed in Table 5. Breaking load values were calculated on the basis of a sample of 1/8-in. by 1-in. cross section, and the theoretical resin breaking loads were computed by assuming a 9,000-lb. per sq.-in. tensile strength for the resin and multiplying by the resin content of the sample. Breaking loads of stretched Samples Nos. 25, 26, and 27 are nearly equal to the breaking loads of the fabrics, and total elongations at break, including elongation from stretching, approach the elongation of about 16 per cent of Orlon fiber at its breaking point. These results indicate that the tensile strength of impregnates in the stretched condition is largely a function of fabric strength, with the resin supporting practically none of the load. This behavior is in contrast to what appears to happen with the unstretched impregnates where elongations were small and approximated the elongation of about 4 per cent found in Plexiglas at its breaking point. Breaking loads of these impregnates were well below those of the fabrics and approached the theoretical breaking loads that could be supported by the resin alone. Sample No. 24 represents an intermediate case.

TABLE 5

Comparison of Unstretched vs. Hot-Stretched Impregnates

	Unstretched		Stretched 5%		Stretched 10%	
Sample No.	1	2	24	25	26	27
Fabric No.	3,970	MS33	3,970	MS33	3,970	MS33
Number of plies	8	10	8	10	8	10
Resin content, % by vol.	72	62	73	64	73	64
Tensile strength, psi	6,910	7,420	8,230	12,000	9,690	12,300
Tensile modulus, psi	560,000	552,000	509,000	641,000	503,000	650,000
Elongation at break, %	2.5	4.0	4.6	5.7	4.5	4.8
Bearing strength, psi	7,890	9,130	...	...	...	8,840
Maximum bearing stress, psi	20,900	24,500	...	...	...	24,900
Elongation at maximum, in.	0.032	0.055	...	...	...	0.068
Flexural strength, psi	12,000	15,300	...	...	...	19,000
Flexural modulus, psi	515,000	609,000	...	...	...	648,000
Deflection at maximum, in.	0.190	0.330	...	...	...	0.314
Tensile breaking load, lbs.	864	928	1,030	1,500	1,210	1,540
Breaking load fabric, lbs.	1,220	1,550	1,220	1,550	1,220	1,550
Breaking load resin	810	696	821	720	821	720

Thus, it appears that the fabric present in unstretched impregnates supports only a small fraction of the applied load since it is probably present in a relaxed condition and thus not able to support the initially applied load in an effective manner, thereby placing the resin under high stress. A tensile load is probably supported initially in unstretched impregnates by the resin and a few threads of the fabric which then fail with the development of resin fissures, which in turn cause local fiber failure when the applied load equals the combined breaking strength of the resin and these fibers. This load is then transferred to the surrounding unbroken fibers in a stepwise manner, with resin failure continuing in the same locality until complete rupture occurs.

This description is probably more typical of failure in impregnates made of fabrics other than nylon. With nylon fabrics ultimate tensile failure occurred after the resin had completely broken up and the final load was supported by the fabric alone. The breaking loads of unstretched nylon impregnates were less than those required to break the uncoated fabric indicating a stepwise failure of the fabric due to the reasons already cited. However, because of the low modulus of nylon (approximately $^1/_5$ that of the resin), most fibers were not broken during initial resin failure and were able to support the load long after the resin had cracked away. Ultimate strength values were high in the nylon impregnates because of the higher fiber strength.

Conclusions

Synthetic fabric impregnates are superior to glass fabric impregnates for the aircraft canopy edge attachment application since they have thermal coefficients that are nearly equal to those of cast acrylic resin. This largely eliminates thermally induced stresses at cemented joints. In addition, the moduli of elasticity of synthetic fabric impregnates are more nearly equal to the modulus of canopy glazing materials than are the moduli of glass fabric impregnates so that the design of cemented joints with a minimum of stress concentration may be more readily accomplished.

Strength characteristics of the synthetic fabric impregnate are also adequate for the canopy attachment application but, in general, are not equal to the strength properties of glass fabric impregnates. Synthetic fabrics have strengths and moduli which are of the same order as those of acrylic resins and thus offer little reinforcement but do reduce resin notch sensitivity.

Orlon fabric appears to be the best synthetic fabric for impregnates used as canopy edge attachments; but the best type of fabric construction is dependent on specific design considerations.

Optimum impregnate properties, limited only by the strength of the fabric, may be obtained by stretching the impregnate at elevated temperature so that the fabric that tends to become relaxed during impregnate construction may be stiffened and thus made capable of supporting an applied load more effectively.

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Flight-Test Instrumentation—

Engineering and Instruments

GILBERT L. ROTH*

Temco Aircraft Corporation

Introduction

Nothing presents the aircraft designer with a better evaluation and understanding of his designs than does prototype flight testing. This knowledge of aircraft flying qualities and equipment performance under actual flight operation is essential to the development of today's aircraft and tomorrow's new designs.

With the ever-growing prominence of flight-test instrumentation, due to advances in speed and altitude capabilities of new aircraft, has come recognition by the aircraft industry of this new branch of aeroengineering. The required flight-test data are obtained through the use of instrumentation devices created and installed under the direction of a specialist. This specialist, the instrumentation engineer, is a man with a technical background in all phases of aircraft design and production technique and in his own field—instrumentation.

The obvious fact cannot be denied that the days of haphazard instrumentation design and installation are over; today the flight-test aircraft is designed with flight-test instrumentation as an integral part of the air frame and its equipment items.

Background

To realize the change in the complexity of flight-test instrumentation since the early days requires just a moment's thought. The "wire-and-strut" airplane of the Wright brothers had several useful instruments—a tachometer to measure propeller r.p.m., an anemometer to measure air speed, and a stop watch. Present-day high-speed, high-altitude aircraft contain hundreds of instruments for normal flight and thousands during flight test.

Between 1903 and 1939 the aircraft designers based most of the flight-test analysis on flight-test data recorded on a knee pad by the pilot or his observer. This was due in part, perhaps, to the costs and time involved in using the bulky and not always reliable instrumentation available during that period. In addition, the performance characteristics of the aircraft were of such a nature that there was no need for much of the data that is required today. With the advent of war in 1939, the necessary research and development required to produce high-performance military aircraft equal to or better than the enemy's brought about a revolution in flight-testing procedure and, in turn, in flight-test instrumentation. This trend carried on to the present necessitated a monumental increase in the types, quantity, quality, recording rate, and size of instrumentation.

Presented at the October 13, 1954, meeting of the IAS Texas Section.

* Thermodynamics Section Head, Aerodynamics Group.

The author is indebted to Clyde Murtaugh for his many valuable comments on the text and to Henry Schoenfeldt and Robert Kershner for their production of illustrations, photographs, and slides.

Section I—Instrumentation Engineering

Since the instrumentation engineer has a position involving many facets of aeronautical work, this paper shall be limited in its scope. The items noted here will be discussed in a manner that will, I hope, create a desire on the part of all aeroengineering personnel to know their flight-test and test instrumentation people better. We shall concern ourselves with the following:

(1) A brief discourse on the procedure followed by a flight-test instrumentation engineer in accomplishing his job.

(2) A discussion of some typical devices the design engineer will most likely require of the flight-test instrumentation engineer during the flight-test program.

The "spade work" concerns itself primarily with collating and correlating the test data requirements so that three distinct instrument classes may be set up. These classes are:

(1) Same instrumentation used in more than one type of demonstration tests. (Stability and control, power-plant, anti-icing types of tests all use, for instance, air-speed and outside air temperature instruments.)

(2) Instrumentation used in only one type of demonstration. (Engine cooling air temperature is of value in power-plant tests only.)

(3) Novel devices requiring special design, installation, and research and development.

Following this basic information are the "original" cost estimates comprising the expected man-power requirements, equipment needs, and maintenance costs to the customer. A rule-of-thumb method for calculating the total number of man-hours needed by the instrumentation group can be based on the number of installations (sensing devices) which are to be installed, regardless of type. Multiply the total number of required installations by an empirically determined factor of twelve to obtain total hours required by average drafting personnel. Add to this value of hours an

additional 25 to 35 per cent of the total hours for service and maintenance of the equipment. Hours required for report writing, correspondence, design, and similar work performed by the instrumentation engineer may be estimated using a time factor of 6 hours per instrumentation item. The factor twelve and the maintenance percentage should be modified by the following:

(1) Personnel experience and capabilities above and below company average.

(2) Proportion of difficult to simple sensing devices—i.e., one-half plus (total units minus thermocouple units) divided by total units. It has been found that the thermocouple and/or temperature sensing units are a good indication of the scope of work to be accomplished.

(3) The type of ship—i.e., large or small—and whether it is other than the first of a series to be instrumented.

Table 1 indicates a typical evaluation of the man-hour requirements for a medium-sized, two-engined turbojet plane. Not all of the problems that occur during the term of the project can be accounted for; nonetheless, these estimates should be reasonably close to the final figures. One item that helps to confuse and cause a breakdown of the estimates is the addition and modification of sizable quantities of instrumentation not originally called for by either the customer specification or the engineering designers. Vacillation on the part of the groups requiring and requesting instrumentation must be eliminated if a thorough, clear-cut job of flight-test instrumentation is to be carried out.

After a careful perusal of the aircraft involved and personal interviews with interested engineering groups, a preliminary Instrumentation Report is circulated for critical analysis so that a final report may be drafted as early as possible. Of particular interest are the suggestions put forth by the flight-test personnel who will fly and qualitatively analyze the airplane.

In many instances compromises must be made between the desired instrumentation and that which is available and practical to use. This depends upon the aircraft size and complexity, the specifications to be met, and the funds available.

The instrument engineer's relationship with instrument manufacturers is vitally important as most of the excellent equipment used today is purchased. To facilitate matters, the engineer must rely to a large extent on the integrity and ability of these suppliers and their representatives.

The instrumentation program moves along with the design of aircraft itself. This is necessary, as the installation of instrument items is a function of aircraft space provisions. During the period between preliminary preparation and actual installation of equipment, the instrumentation engineer goes through all phases of his work including procurement, laboratory and installation tests, circuitry design, personal liaison, customer contact, installation, and design analysis. Ideas are solidified, changes held to a minimum (consistent with customer requirements), and installations are made within airplane structure and surfaces which are "buttoned-up" in the early stage of production. As the final step, the complete Instrumentation Report is written and distributed.

This, then, completes the instrumentation engineer's work insofar as design and installations are concerned, but, as in any such field of endeavor, changes occur with a monotonous consistency that keeps this specialist on his toes. Thereafter remain the calibration, check-out, and maintenance of the installed instruments.

Section II—Instruments

What are some of the equipment items that are used by the flight-test instrumentation people to obtain the required flight-test data? What types of analytical calculation are accomplished by the instrumentation engineer?

The most commonly used types of instruments are:
(1) Pressure sensors.
(2) Temperature sensors.
(3) Strain gages.
(4) Accelerometers.
(5) Position indicators.
(6) Recorders and supporting items.

Fig. 1 shows several types of pressure sensors. Each has its own sphere of usefulness dependent upon the required location, airplane geometry, range of air speeds, accuracy, and range of uses. The basic performance of the pressure probe, aligned with the fluid flow, may be obtained as follows. The well-known relationship of static to stagnation pressure is

$$\frac{p_s}{p_0} = \left[1 + \frac{k-1}{2} M^2\right]^{k/(k-1)} \qquad (1)$$

Expand the right side of Eq. (1) in terms of a binomial expansion such that

$$(1+x)^n = 1 + nx + \frac{n(n-1)x^2}{2!} + \frac{n(n-1)(n-2)x^3}{3!} + \ldots \qquad (2)$$

in which $x < 1$ for convergence. Taking the result of this expansion and substituting $\rho_0 = kp_0/C_0^2$ we ob-

Table 1
Estimation of Man-Hours to Completion—for a Single Airplane, First of a Series, Twin-Engined Turbojet

Total No. of pressure instruments	57
Total No. of thermocouple temperature instruments	211
Miscellaneous	45
Total	313

(a) Drafting time = 313 × 12 = 3,756 hours
(b) Corrected drafting time = 3,756 × {1/2 + [(313 − 211) ÷ 313]} = 3,100 hours
(c) Engineering time = 6 × 313 = 1,878 hours
(d) Maintenance and service = 30 per cent of 3,100 = 930 hours
(e) Total time (man-hours) required = 3,100 + 1,878 + 930 = 5,908 hours

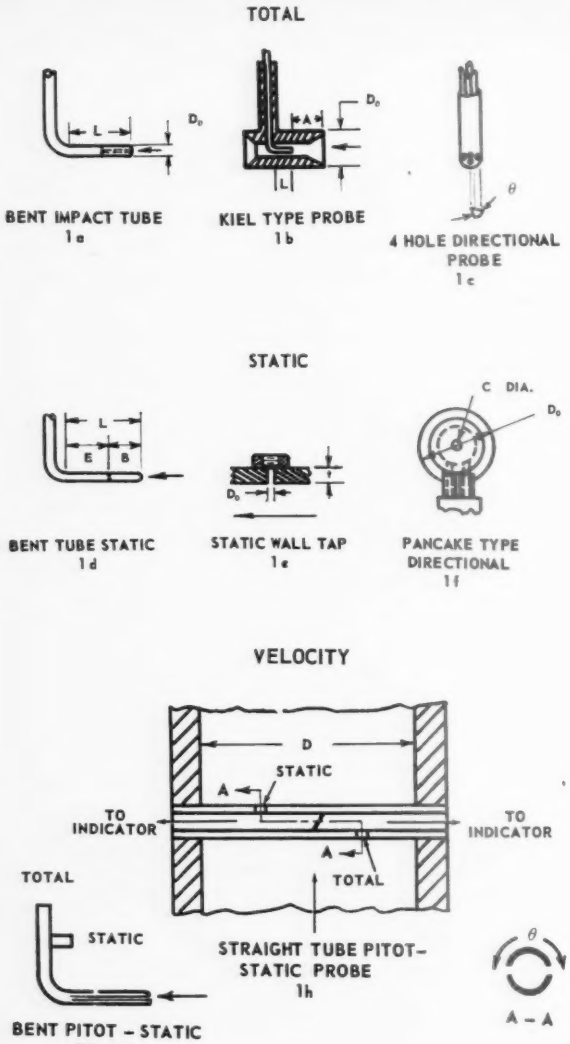
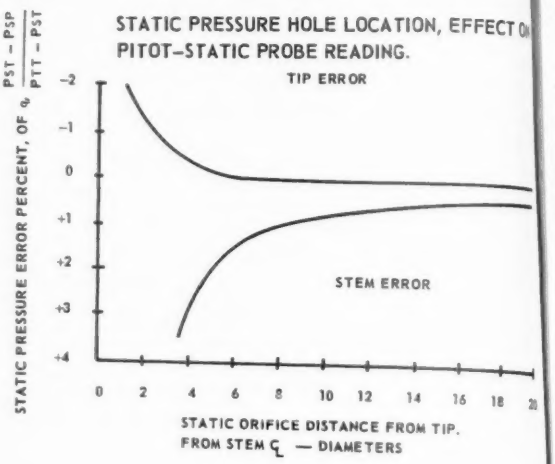


FIGURE 1 — PRESSURE PROBES

FIG. 2a


STATIC PRESSURE HOLE LOCATION, EFFECT ON PITOT-STATIC PROBE READING.
TIP ERROR
STEM ERROR
STATIC PRESSURE ERROR PERCENT, OF
STATIC ORIFICE DISTANCE FROM TIP. FROM STEM — DIAMETERS

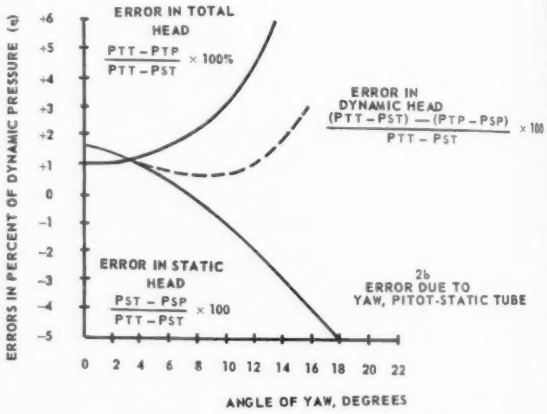
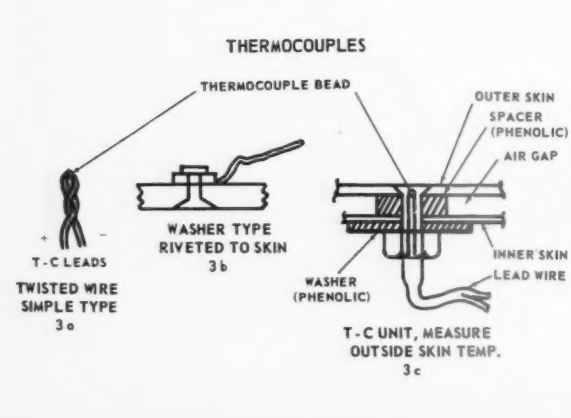

ERROR IN TOTAL HEAD
ERROR IN DYNAMIC HEAD
ERROR IN STATIC HEAD
2b
ERROR DUE TO YAW, PITOT-STATIC TUBE
ERRORS IN PERCENT OF DYNAMIC PRESSURE
ANGLE OF YAW, DEGREES

FIG. 2: PRESSURE PROBE ERROR CURVES



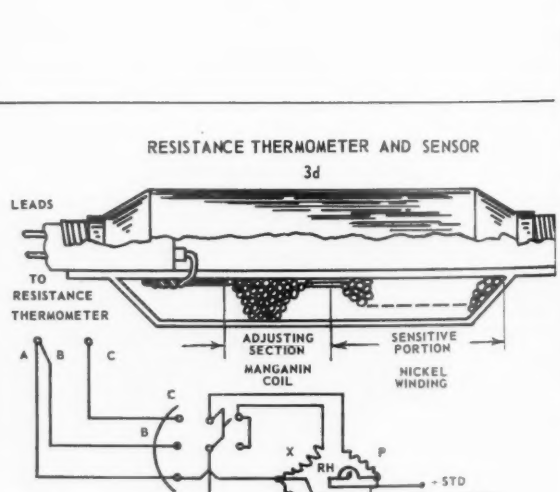


FIGURE 3 — TEMPERATURE SENSORS

tain a theoretical equation,

$$p_s = p_0 + 1/2\ \rho_0 V_0^2 \left[1 + \frac{M^2}{4} + \left(\frac{2-k}{24}\right) M^4 + \ldots\right] \tag{3}$$

To account for the nonperfect probe used, a calibration factor K is introduced into Eq. (3). The equation so modified does not account for the actual viscous and inertia forces acting upon the probe itself which has finite dimensions. Thus it would seem reasonable to indicate this fact by introducing a function of Reynolds Number, $[f(R_e)]$. Thus

$$p_s = p_0 + (1/2)K\rho_0 V_0^2[f(M^2), f(R_e)] \tag{4}$$

Nomenclature for Eqs. (1) through (4):

C_0 = velocity of pressure propagation, free-stream
k = ratio of specific heats, C_p/C_v
K = calibration factor
M = Mach Number
p_s = stagnation pressure
p_0 = static free-stream pressure
R_e = Reynolds Number
V_0 = velocity in free stream
ρ_0 = density in free stream

Thus the ideal probe is one that can be calibrated over the entire range of Mach Numbers and Reynolds Numbers of the flow in which it will be located. The impact orifice measuring stagnation pressure is little affected by Reynolds Number, but the static readings are adversely affected when Reynolds Number is less than 2,300 (for static tubes, not wall taps).

Probe size and location depend upon several factors: (1) desired accuracy and (2) relationship to the geometry in which it is located—e.g., in a duct or external to the aircraft. Table 2 is a compilation of probe parameters and variables for the pressure sensors shown in Fig. 1. Experience indicates that the probe cross-sectional area should be not more than approximately $1^1/_2$ per cent of the cross-sectional area of the test section. The location of the probe should be such that it does not interfere with the test itself.

The per cent error of a pressure probe reading may be stated arbitrarily as

$$\text{per cent error} = \frac{\text{actual value} - \text{probe test value}}{\text{actual value of velocity press}} \tag{5}$$

Thus a positive error indicates a probe reading less than the actual pressure value. Fig. 2 indicates the type of error curve obtained for a pressure probe. These error correction curves are the result of runs with a calibrated probe.

The most commonly used temperature sensing devices (shown in Fig. 3) are as follows:

(1) Thermocouple, generating its own electromotive force.

(2) Resistance thermometer and sensor, using external power supply.

(3) Mercury thermometers of conventional commercial design.

The proper use of thermocouples presents many problems, such as location, size, calibration, and geometry. Geometry is shown in Fig. 3, but it is by no means a complete indication of all geometric shapes possible. The choice of location of thermocouples depends on many things. It must be so spotted that it senses the proper temperature. This may sound a little farfetched, but in many cases the temperature sensing device has been known to read something other than that desired, as, for example, the surface temperature of a structure with airflow over it. The thermocouple must be situated so that it does not protrude above the surface, and, actually, it should be slightly recessed so as not to sense boundary-layer air temperature.

Fig. 4 indicates types of parallel circuits normally used when desiring a weighted average temperature such as turbojet engine tailpipe values. The parallel thermocouple system with common branch points (Fig. 4b) can be designed to give a minimum of circuitry error by making all leads have the same value of resistance. However, practical difficulties of constructing such a harness may outweigh the greater circuitry errors in a harness of the ladder type. Circuitry error is defined as the difference between the temperature indicated by a network of paralleled thermocouples and the average of the temperatures of the individual junctions. This error is a function of the ratio of the resistance of the bus wire (common connection point) between junctions and the resistance of the thermocouple between junctions. Circuitry error is zero when the ratio of bus lead resistance to thermocouple resistance is zero. It is also zero when parallel thermocouples of equal resistance are connected to common branch points.

Resistance-type temperature sensing elements consist of a wire coil or resistance which varies in resistance with temperature variation. An e.m.f. is impressed on the resistance system, and with change in resistance there is a change in voltage drop. This is indicated on a resistance thermometer, which is an active part of this type of setup.

In private correspondence with NACA Langley and Lewis Laboratories the author asked the following question: "With the great variety of thermal measuring devices now in use, the question of which device

TABLE 2
Some Probe Parameters (See Fig. 1)

Type	Outside Diameter (Approx.)	Length Ratio, L/D_0	Distance from Wall, $Y_{min.}$	Notes
Bent impact tube	$0.05D$	$7^1/_2$–10	$0.15D$	...
Kiel-type probe	$^1/_8$–$^1/_4$ in. ($0.05D$ max.)	2–$2^1/_2$	$0.15D$	$^1/_2 = A/D_0$
4-hole directional probe	0.135 in.	...	$0.15D$	$55° = \theta$
Bent tube static	$0.05D$	16–21	$0.15D$	$8 = B/D_0$
Static wall tap	$^1/_8$–$^3/_4$ in.	...	$0.15D$	$2 = t/D_0$
Pancake-type directional	20 mm.	3–5 mm. in thickness	$0.15D$	1.5 mm. $= C$
Bent pitot-static	$^5/_{16}$ in.	21	$0.15D$	...
Straight tube pitot static	$0.1D$	...	...	33°–180° $= \theta$

D = pipe diameter
D_0 = outside diameter of probe
Y = probe ℄ distance from duct wall

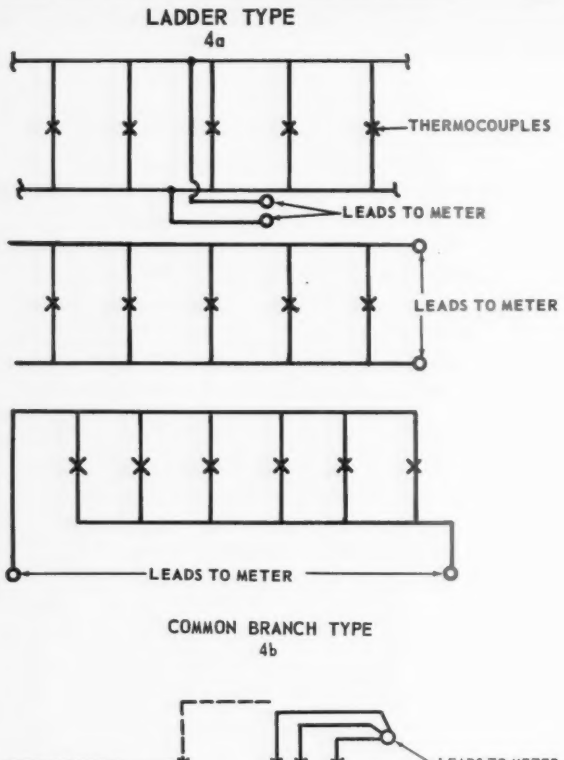


FIGURE 4—PARALLEL CIRCUITS FOR THERMOCOUPLES

best suits a particular application often arises. With respect to (1) ease of manufacture, (2) service life, (3) maintenance, and (4) cost, what is the proper device to use for a given application and range?" The applications noted were for engines, structures, air, and transparent materials in the range −60°C. to +1,500°C.

The personnel of the NACA laboratory replied in quite some detail on the subject, and a brief outline of the major points contained in their replies is given here.

Langley Aeronautical Laboratory

(1) Although the resistance thermometer has greater inherent accuracy, greater electrical output for a given change in temperature, and no "cold junction" problems, thermocouples are used for all possible applications because of their small size, great flexibility, and superiority on the above-mentioned points.

(2) For applications in which structural skin temperatures are desired, thermocouples peened into the metal are generally used. Note Fig. 5b. A gage as small as No. 30 wire in thin skins subjected to 500°F. air at Mach Number 2.0 has been used without excessive thermocouple mortality.

(3) In the case of hot air temperatures, stagnation or total temperature is measured in all cases. No device is known which will accurately measure the static temperature of a high-velocity gas. In the range of 450° C., at Mach Numbers 1.0 to 6.0, a stagnation probe, shown in Fig. 5a, is applicable.

(4) To measure surface temperatures of transparent materials, an insert method has been used. The thermocouple is first soldered to a small metal disk. The disk is then cemented into a hole in the specimen so that the disk surface is flush with the specimen surface. Disk material is usually copper or brass.

Lewis Flight Propulsion Laboratory

(1) It has been found that the thermocouple, in many cases, is the best thermal measuring device to use to measure the multitude of temperatures surrounding an aircraft and its engine.

(2) The ease of manufacture and cost of thermocouples are a function of the facilities and skilled labor available to you. Service life and maintenance are usually a function of the caliber of the mechanics handling the instrumentation.

(3) Measurements of static temperatures are quite difficult and are usually avoided. It is more advisable to measure the total temperature and then compute the static temperature from knowledge of the static to total pressure ratio. A scheme for measuring static temperature which may be of use appears in "Development of the NRL Axial-Flow Vortex Thermometer," by Ruskin, Schecter, Ringer, and Merrill, Naval Research Laboratory Rep. 4008, September, 1952.

(4) Fig. 5b shows the method of attaching thermocouples to surfaces as employed by the Icing Research Group at the Lewis Laboratory. These units last about 6 months with little or no maintenance.

The measurement of strain is accomplished by a system composed of the following components:

(1) Strain gage.

(2) Balancing circuits and controls, as the strain gage is usually a part of a bridge circuit.

(3) Regulated power supply.

(4) Amplifier unit(s) if required to increase gage output signal.

(5) A recorder, which is generally either oscillograph, oscilloscope, or strip-chart type.

(6) Calibration equipment.

The strain gage normally used on flight-test aircraft is of the "resistance type." This type of gage bases its operation on the fact that, as an electrically conducting wire is stretched, its resistance increases, and, if compressed, its resistance decreases. Fig. 6 shows a single strain gage attached to a section of structure so as to measure the strain in a given direction (x-direction).

To produce a measurable current or voltage output proportional to the strain or resistance change of a gage it is necessary to use a bridge circuit. This bridge circuit permits indirect measurement of the change in gage resistance, which in most cases would be impossible if measured directly. As an example, take a gage with

a total resistance of 120 ohms and a change in gage resistance of 0.125 ohm based on a reasonable value of structural stress. Assuming a preferred maximum allowable error of ±2 per cent of the maximum stress value, the tolerance in reading the change in resistance would be ±0.0025 ohm for a total resistance measurement of 120 ohms. This is an accuracy of $\pm^{2}/_{1,000}$ of 1 per cent which is not normally obtainable with direct measuring equipment.

Figs. 6a through 6g indicate the various methods of setting up the strain gages for measurement.

Accelerometers are used in general to determine the aircraft structural loads. Recent developments have brought about an accelerometer device that is used to maintain altitude during normal flight by taking note on a dial of the acceleration changes occurring during vertical aircraft movements. This device can be used as a "rate of descent" unit. Two types of accelerometers generally used in flight test are the self-contained dial readers and the transducer units that submit an electrical variation to a recording device.

Position transmitters are usually electrically operated devices, such as potentiometers, autosyns, etc., which are "read-out" on electrically operated dial instruments. Their size, shape, and power requirements are as varied as there are installations in an aircraft.

One of the most complex of endeavors within the instrumentation field is the data-recording and indicating devices. Some of the types normally used in flight test are:

(1) Photo-recording panel system (camera taking pictures of a panel of instrument dials).
(2) Camera recording.
(3) Oscillograph.
(4) Pen recorders.
(5) Oscilloscope.
(6) Dial instruments.
(7) Digital recording instruments.

A photo-recording panel is shown schematically in Fig. 7. It can be seen that the lighting of such a recording device is a major problem. The setup shown has been in use for several years and permits excellent pictures to be taken of all instruments on the panel with black and white, 35 mm., plus X, or super XX film and an f/2.7 lens.

Various cameras are used to record those portions of tests that can be analyzed and demonstrated only through the use of both movie and still films. These cameras have exposure rates from 1 frame per sec. to over 16,000 frames per sec. Tests typical of those that involve the use of cameras are:

(1) Ejection seat.
(2) Bomb drop.
(3) Rocket firing.
(4) Escape chute (hatch).
(5) Flutter and vibration.

Oscillographs, oscilloscopes, and other recorders all are used to either record or indicate sensed quantities by means of electrical impulses. Dial instruments are either electrically or pneumatically operated.

A sample of the work involved in obtaining accurate recording of data is shown by the following measurement of thermocouple sensed temperatures on parallel dial indicators. For the purposes of accuracy in a circuit where more than one instrument is connected to one thermocouple or thermopile, the lead resistances (see Fig. 8) must be accurately adjusted in accordance with the following solution. This method evolves an accurate determination of the individual instrument lead resistances required. The required resistances are R_{L_1} and R_{L_2} (note Fig. 8).

Nomenclature for Eqs. 1 through 17:

e_1, e_2, e	=	voltage drop across either instrument circuit
e_t	=	voltage generated by the thermocouple or thermopile at the temperature that corresponds to instrument full-scale deflection
R_{I_1}	=	instrument No. 1 internal resistance
R_{I_2}	=	instrument No. 2 internal resistance
R_{L_1}	=	lead resistance in instrument No. 1 circuit
R_{L_2}	=	lead resistance in instrument No. 2 circuit
i_1	=	current flow through instrument No. 1

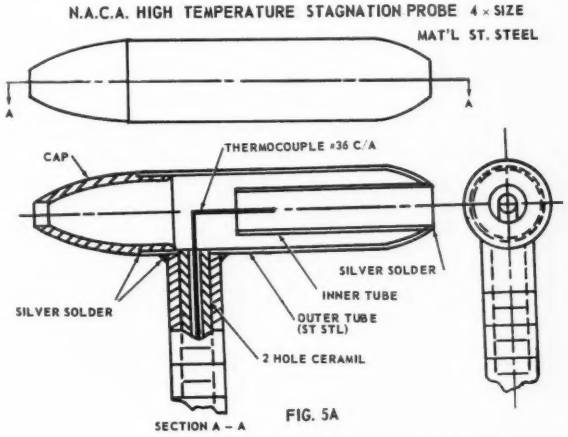


FIG. 5A

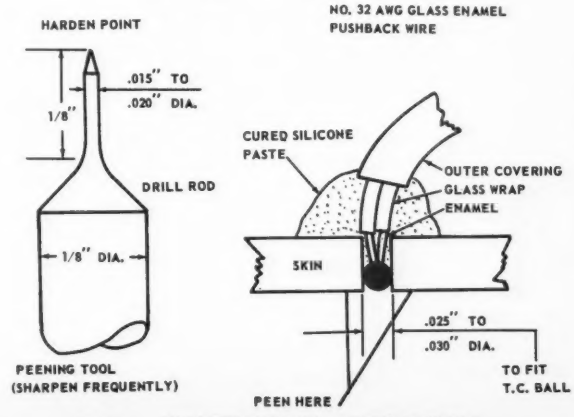


FIG. 5b NACA PEENED SKIN — THERMOCOUPLE

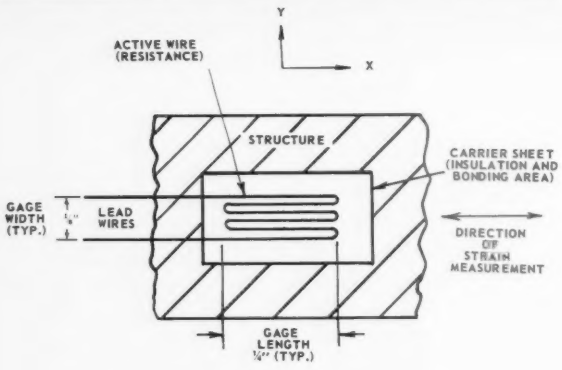
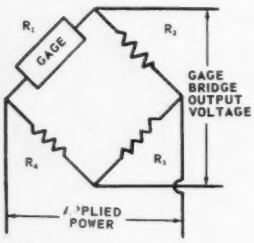
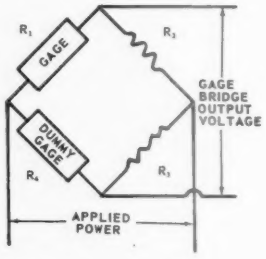


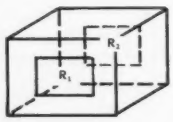
FIGURE 6 — RESISTANCE WIRE STRAIN GAGE

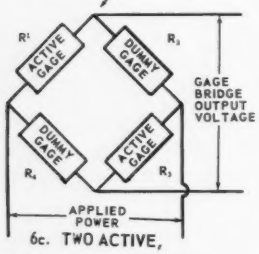


6a.

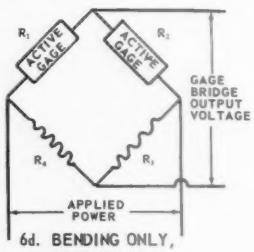


6b. TEMP. COMPENSATION

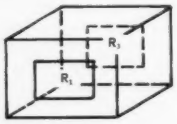


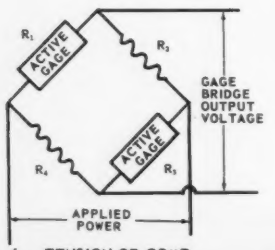

TWICE THE OUTPUT OF FIGURE 6b. GAGES ON SAME SIDE OF STRUCTURE
ACTIVE GAGE
DUMMY GAGE
GAGE BRIDGE OUTPUT VOLTAGE
APPLIED POWER

6c. TWO ACTIVE, TWO COMPENSATING GAGES

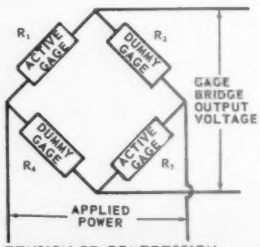


6d. BENDING ONLY, TEMP. COMP.

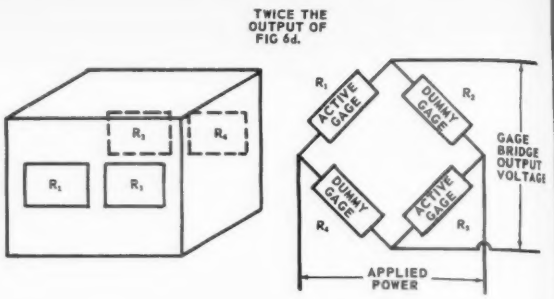




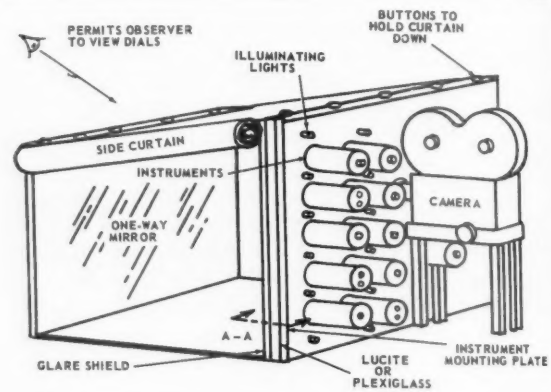
6e. TENSION OR COMP., NOT TEMP. COMP.



6f. TENSION OR COMPRESSION, TEMP. COMPENSATED.



6g. BENDING ONLY, TEMP. COMPENSATED



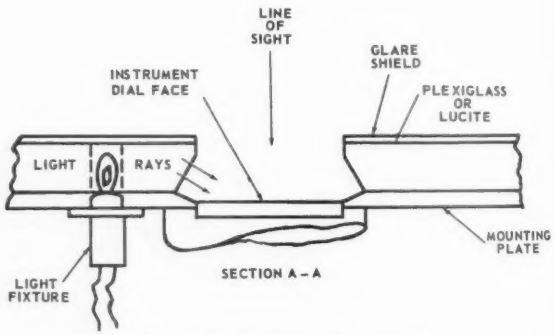


FIG. 7. Photo-recording panel.

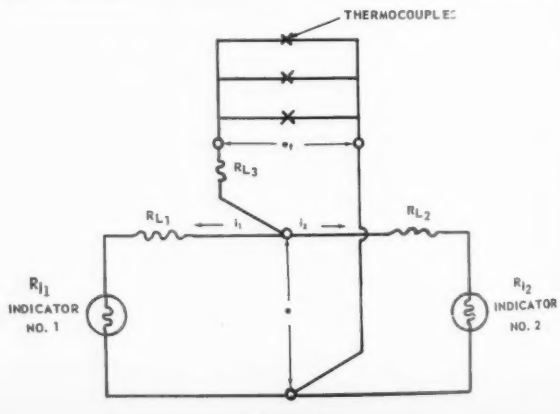


FIGURE 8
PARALLELING OF TEMPERATURE INDICATORS–THERMOCOUPLES

i_2 = current flow through instrument No. 2
R_{L_3} = resistance of thermocouple circuit including thermocouple(s)
R_{N_1}, R_{N_2} = thermocouple and thermocouple lead resistance when using one indicator

$$e_1 = i_1[R_{L_1} + R_{I_1}] \quad (1)$$

$$e_2 = i_2[R_{L_2} + R_{I_2}] \quad (2)$$

$$e_1 = e_2 = e \quad (3)$$

Since e, R_{I_1}, and R_{I_2} are known

$$i_1 = e/(R_{L_1} + R_{I_1}) \quad (4)$$

$$i_2 = e/(R_{L_2} + R_{I_2}) \quad (5)$$

$$e_t = [i_1 + i_2]R_{L_3} + e \quad (6)$$

and substituting for e

$$e_t = [i_1 + i_2]R_{L_3} + i_1[R_{L_1} + R_{I_1}] \quad (7)$$

$$e_t = [i_1 + i_2]R_{L_3} + i_2[R_{L_2} + R_{I_2}] \quad (8)$$

therefore

$$R_{L_1} = \frac{e_t - (i_1 + i_2)R_{L_3}}{i_1} - R_{I_1} \quad (9)$$

$$R_{L_2} = \frac{e_t - (i_1 + i_2)R_{L_3}}{i_2} - R_{I_2} \quad (10)$$

or

$$R_{L_1} = \frac{e_t - R_{L_3}i_2}{i_1} - R_{L_3} - R_{I_1} \quad (11)$$

$$R_{L_2} = \frac{e_t - R_{L_3}i_1}{i_2} - R_{L_3} - R_{I_2} \quad (12)$$

The value of e_t will remain constant whether one or two instruments are used, and, if we use this such that R_{N_1} and R_{N_2} refer to the lead and thermocouple resistance when one indicator for each is used,* we have

$$e_t = i_1[R_{N_1} + R_{I_1}] \quad \text{or} \quad i_1 = \frac{e_t}{R_{N_1} + R_{I_1}} \quad (13)$$

$$e_t = i_2[R_{N_2} + R_{I_2}] \quad \text{or} \quad i_2 = \frac{e_t}{R_{N_2} + R_{I_2}} \quad (14)$$

Substituting Eq. (13) in Eq. (11) and Eq. (14) in Eq. (12) we have

$$R_{L_1} = \frac{i_1(R_{N_1} + R_{I_1})}{i_1} - R_{L_3}\left[\frac{R_{N_1} + R_{I_1}}{R_{N_2} + R_{I_2}}\right] - R_{L_3} - R_{I_1} \quad (15)$$

$$R_{L_1} = R_{N_1} - R_{L_3} - R_{L_3}\left[\frac{R_{N_1} + R_{I_1}}{R_{N_2} + R_{I_2}}\right] \quad (16)$$

$$R_{L_2} = R_{N_2} - R_{L_3} - R_{L_3}\left[\frac{R_{N_2} + R_{I_2}}{R_{N_1} + R_{I_1}}\right] \quad (17)$$

The value of R_{N_2} and R_{N_1}, the normal instrument lead resistance rating, varies but is usually 2 ohms, 8 ohms, or 22 ohms. The value of R_{L_3} should be kept to a minimum and internal resistance of the instruments kept as nearly equal as possible. If $R_{N_1} = R_{N_2}$ and $R_{I_1} = R_{I_2}$, then $R_{L_1} = R_{N_1} - R_{L_3} - R_{L_3} = R_{N_1} - 2R_{L_3}$. Thus, if R_{L_3} is equal to or greater than $^1/_2$ of R_{N_1}, the value of R_{L_1} is in the negative. This cannot exist physically and would require a decrease in R_{L_3} or an increase in R_{N_1} such that R_{L_1} has a positive value.

Digital recording machines are in use in industry, but few, if any, have been designed or are in use in actual flight testing of aircraft. The author initiated and carried out a program that brought about the design and building of a high-speed analog-to-digital recording machine. The following is a brief discussion of this apparatus; Fig. 9 shows a section of the completed strip chart.

The complete recording system consists of the following subcomponents:

(1) A high-speed digital recorder such as the Analex Company's "Synchroprinter," capable of 600 printed characters per sec.

(2) A control center assembly that is used to control the entire recording operation.

(3) Analog-to-digital converters that consist of an electromechanical-null-balance measuring system, or an all-electronic measuring and digital converting system.

(4) A switch assembly that selects the proper variable to be measured and presents it in proper order to the analog-to-digital converter.

(5) An indicator to synchronize time of the recorder with other recording equipment such as photo-panels, oscillographs, etc.

(6) A power supply capable of supplying highly regulated d.c. voltage to transducers, and converter.

All of this equipment, when combined, is capable of measuring temperatures and pressures (positions, if fast acting) and other electrical impulses at a rate of 18 individual points per sec.—or a total of 2 lines (see Fig. 9). This value will be increased, as experience is gained, to a value of 4 lines per sec. with an electromechanical measuring system—or to 15 lines (135

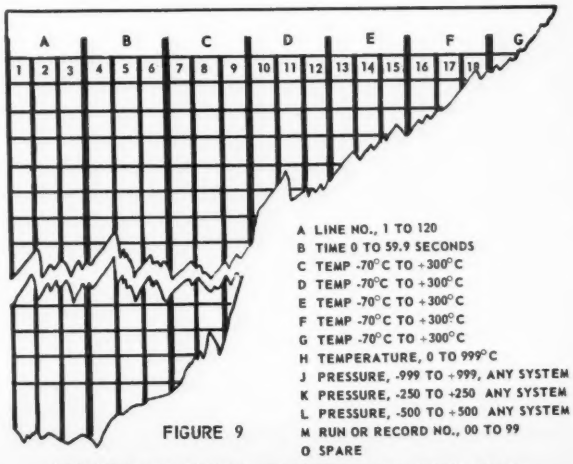

A
B
C
D
E
F
G
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
A LINE NO., 1 TO 120
B TIME 0 TO 59.9 SECONDS
C TEMP -70°C TO +300°C
D TEMP -70°C TO +300°C
E TEMP -70°C TO +300°C
F TEMP -70°C TO +300°C
G TEMP -70°C TO +300°C
H TEMPERATURE, 0 TO 999°C
J PRESSURE, -999 TO +999, ANY SYSTEM
K PRESSURE, -250 TO +250 ANY SYSTEM
L PRESSURE, -500 TO +500 ANY SYSTEM
M RUN OR RECORD NO., 00 TO 99
O SPARE

FIGURE 9
ANALOGUE TO DIGITAL RECORDER DATA STRIP CHART

* R_N and R_{L_3} represent the same type of resistance, R_N with one instrument and R_{L_3} with parallel instruments.

points) per sec. with an electronic measuring device, this being the maximum speed of the present digital printers.

The accuracy of this machine is ±1 digit or ±1 part in 1,000 (each record point is made up of 4 digits), depending on the full scale of the individual column of measurement.

The automatic analog-to-digital recording machine is constructed so that it is operable in the following ranges:

(1) Altitude	0 to 65,000 ft.
(2) Temperature	−75°F. to +165°F.
(3) Vibration	±5*g*'s, 0 to 550 cycles per sec.
(4) Acceleration	7*g*'s steady state
(5) Humidity	90 per cent maximum

The physical dimensions and weights are as follows:

(1) Recorder	125 lbs.	2 by $1^1/_2$ by $1^1/_4$ ft.
(2) Control assembly	50 lbs.	$1^1/_2$ by $^2/_3$ by $^1/_3$ ft.
(3) Analog-to-digital converters	60 lbs. each	1 cu.ft.
(4) Switch assemblies	3 lbs. each	6 by 4 by 4 in.

The number of switch assemblies is dependent on the setup desired. Each switch has a capacity for ten variables, but through a switching arrangement it would be possible to use each one for additional variables. This additional switching would cause a problem in identifying the data points taken.

For each measuring channel (vertical columns in Fig. 9) one analog-to-digital converter is required.

This machine has not been flight tested as yet but should be in operation by the end of this year. Most of the components are commercially available units of a high degree of manufacturing precision.

Recommended Instrumentation Development

Many instrumentation installations are of a complex nature because solution by a simpler method has not been fully developed. Therefore, the development of the following items is suggested:

(1) Instantaneous and direct in-flight thrust measurement of turbojet engine installations. Use of strain gage method might resolve the problem.

(2) Gas sensing probes and recording devices that are capable of presenting a rapid record of the percentages of constituents within fuel tanks, fuel bays, armament bays, and the like.

(3) Highly accurate and instantaneous rate of roll and pitch sensing devices.

(4) Self-contained rate of descent indicators (sinking speed) at point of contact with water or solid surface.

Conclusions

Discussion of the engineering and instruments of flight-test instrumentation should, it is hoped, present a better picture of the complexities facing the flight-test instrumentation personnel. With this in mind, the aircraft designer should remember the instrumentation for the next aircraft he works on. It is for his benefit, and the customer's, to integrate all systems into the aircraft design.

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Taming TITANIUM

DAVE ADAMS*

Ryan Aeronautical Company

Introduction

Under a prime contract with the U.S. Air Force, Ryan Aeronautical Company has just completed a comprehensive study of titanium. In what may be the most extensive report of its type, the results of this investigation will be made available to the aircraft industry. The objective is to familiarize industry plants with the best methods for fabricating air-frame and engine components from titanium.

Conducted by Ryan's Engineering Division, the study was restricted to sheet-metal manufacturing techniques and commercially pure titanium. Every process involved in sheet-metal fabrication—such as forming, welding, riveting, grinding, sawing, drilling, cleaning, annealing, and dimpling—was analyzed.

Although metallurgical methods were generously employed to determine results, the study is not intended to be a theoretical metallurgical inquiry into the reasons why titanium behaves as it does. Emphasis is placed upon the practical question of how to apply manufacturing techniques to titanium sheet. As much as possible, standard aircraft machines and facilities are used to evaluate methods so that the information can be directly applied. Comparisons are drawn between recommended methods for fabricating titanium and those used with stainless steel.

An important advantage of the report stems from the fact that it is a coordinated, packaged study covering all phases of the manufacturing problem. Much has been written about titanium. Most of the data published is confined to a single fabrication method or is a highly specialized inquiry into one phase of titanium behavior. The manufacturer who contemplates using titanium is faced with a time-consuming task of research and fact-gathering to assemble the practical information upon which to proceed.

Almost nonexistent as a pure metal 5 years ago, titanium has enjoyed a spectacular growth. Inevitably, it will mushroom to impressive proportions in the aircraft industry because of the weight-saving advantages offered within certain temperature ranges.

Two factors inhibiting its wider use are its relatively high cost and the dearth of knowledge on how to adapt the white metal to present factory facilities. Undoubtedly, the dissemination of the report will stimulate greater use of titanium in industry. In turn, this will have a salutary effect upon costs because of the stepped-up volumes of metal which the producers will be permitted to process.

The most important manufacturing processes covered in the complete Ryan report are forming and welding. Because of the space limitations necessarily imposed in this résumé, only these techniques will be discussed at length, with brief mention of other processes studied.

* Metallurgist.

Forming

Ryan conducted experiments in both hot- and cold-forming of commercially pure titanium. Drop hammers, punch presses, brake presses, and power rolls were some of the forming tools used. A number of special arrangements were devised to heat the titanium sheets and dies by both mechanical and electrical means.

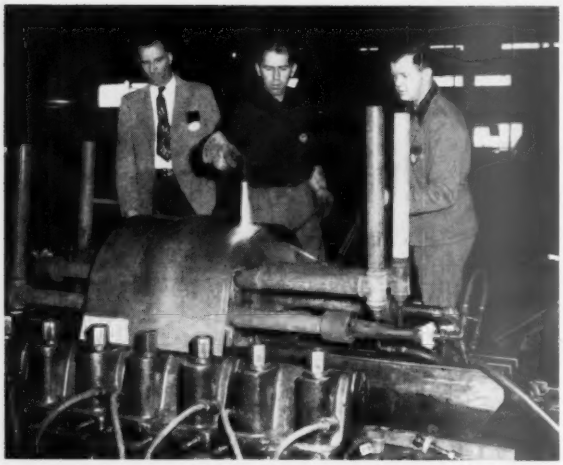
It was felt that the forming operations should embody sufficiently deep forming requirements to be representative of the most severe problems likely to be found in the aircraft industry. For the drop hammer work, blanks of 0.025-in. thickness—ranging in size from 12 in. by 18 in. to 20 in. by 30 in.—were selected. These were formed into semicircular cavities with irregular linear centerlines. Some of the stampings have multiple convolutions of both concave and convex proportions with respect to the die surface. The stampings were assembled into a section of an exhaust collector shroud for a helicopter engine.

Experience showed that parts, other than those embodying shallow draws, could not be cold formed in the drop hammer because the impact caused the parts to fracture in the stage dies after relatively small amounts of deformation. Use of various lubricants did not change this situation. Also, the complex allowances required to compensate for spring back preclude the use of cold-forming for economic reasons.

Hot-forming of titanium in the drop hammer was quite successful when a proper procedure was evolved. Initially, it was decided to use preheated sheets, brought to a temperature of between 900° and 1,000°F. in a holding furnace, and to form them on heated steel staging and finisher dies. Mating punches of cast steel were used with two of the nine punches electrically heated—one with cartridge heaters and the other with Calrod units.

To heat the dies, a portable furnace was connected to a drop hammer of 3,000-lb. head capacity so that molten Hi-temp salt, consisting of sodium and potassium nitrites and sodium nitrate, could be circulated through the die. With a salt temperature of 1,000°F., this arrangement produced a die surface temperature of between 575° and 700°F., depending upon the size of the die. The Calrod-heated punch operated at 300°F.

First stamping operations began by treating the blanks as if they were stainless steel except for the fact that they were preheated. High-temperature forming rubber was placed across the sheet in the flange area



Laboratory engineers experiment with hot-forming of titanium sheet on stretch press equipped with combustion-heated die.

at the edges of the die, and the full impact of the hammer was used. In every instance this resulted in fractures at or immediately below the radiused edge of the die.

Then, a procedure was developed in which the number and position of the rubber pads were varied and the blank was inched down with lighter blows of the hammer. Between each hit, the blank was returned to the furnace and heated to the 900°–1,000°F. range. In this way, the parts were successfully formed. Incidentally, use of dry lubricants—such as Ryan Dry-lube or Everlube—was valueless because of the high furnace heat that burned out the binder, removing the lubricant's adhesive quality. Petroleum-base die lubricants could not be used because of the temperatures of the heated steel dies.

Although these arrangements were capable of forming satisfactory titanium parts on an experimental basis, Ryan does not consider them to be adequate for production purposes. A major objection to the use of heated dies proved to be the changes in die dimensions and configurations. The design of the punch and die required that they be cleared for 0.025-in. material at room temperature. After heating, the blank material seized and galled in local areas because of lack of die clearance. In other areas, the correct contour was not realized because of excessive die clearance.

In order to clear the dies, they must be ground while at operating temperature and in the hammer. This is hazardous and time-consuming. Polishing the radii of the die tended to reduce galling of the material on the corners of the die but did not appreciably affect the tendency of the sheets to fracture because of seizing.

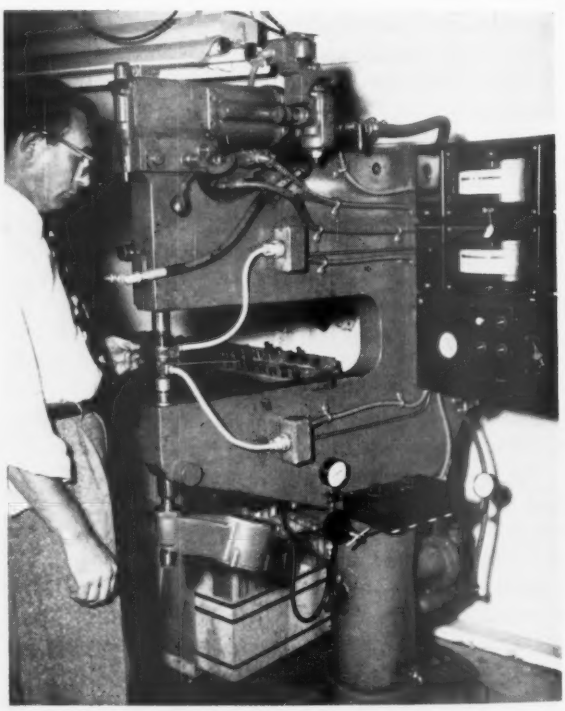
As the stamping experiments progressed, it became apparent that heated dies were not accomplishing the purpose of keeping the blank hot for forming. The temperature drop of the blank in still air is very rapid. When placed in the die, it is supported by the high points only, which does not provide sufficient heat-transfer area to keep the part hot.

In view of these difficulties, it was decided to try the standard technique used to form stainless steels. This involves the use of Kirksite dies and lead punches. To avoid the possibility of lead contamination and prevent the heat from melting the lead, the punches were jacketed with mild steel on their contact faces. A generous coating of heavy-weight commercial oil, SAE 250, was applied to the die to serve as a lubricant and heat insulator.

Using this arrangement, with the blanks furnace heated to 1,000°F., the parts were repeatedly formed with satisfactory results. Temperature tests disclosed that the temperature of the blank, even when using cold tools, was higher than the hottest die temperatures recorded under the previous heated-die method.

This work has shown conclusively that commercially pure titanium parts can be formed as satisfactorily as stainless-steel counterparts without basic engineering design changes other than judicious selection of edge and corner radii at abrupt contour changes and liberal use of stage dies. It is primarily important to maintain blank temperatures at about 700°F. for optimum forming characteristics. Heated dies are not of practical use while cold Kirksite and lead tools offer an inexpensive, safe method for accomplishing the job.

By trial and error it was found that a single pad of forming rubber over the entire blank, with a build-up of smaller pads around the perimeter, gave the best results. As depth of draw increased, the amount of rubber used along the edges was reduced. As the rubber pattern used was worked out, the technique of



Dimpling investigations showed that titanium should be hot dimpled at temperatures between 600° and 700°F. This machine heats dimpling dies by means of encircling resistance coils.

Titanium shroud sections for Piasecki helicopter engines exhibit a variety of manufacturing methods. These have been hot and cold formed, riveted, and resistance welded by Ryan.

inching the hammer down gave way to normal full-impact blows.

The oxides produced by heating, as well as the residual lubricants, were successfully removed by immersion in an 800°F. salt bath followed by a nitric-hydrofluoric rinse.

A number of flanged titanium parts were formed with trapped rubber contained in a heavy steel box attached to the head of a large Cecostamp air hammer. The blanks were heated to 1,000°F. and estimated to be within 600° to 700°F. during forming. A pad of high-temperature rubber was placed over the blank to protect the trapped rubber from the hot metal. Although the parts were successfully formed, the work showed that titanium exhibits strong resistance to the absorption of material in compression flanges.

Ryan also was successful in heating the titanium blanks to the 900°–1,000°F. range electrically, by attaching electrodes to the sheets and passing current through them. This is a practical method that has the advantage that the heating can be done while the rubber pads are being placed, saving some heat loss incurred when the furnace method is used.

Forming was performed on punch presses capable of exerting 105 tons. Best results were obtained in the forming of 0.025-in. sheet titanium by using blanks heated to 900°F. in a furnace. The die was heated to 275°F. with electrical heaters and insulated from the punch press by sheet asbestos.

Cold-forming on the punch press requires greater attention to contour forming of the blanks to permit the metal to flow to the proper die contour. As temperatures drop toward room temperature, the use of lubricants becomes increasingly important. The most successful room temperature forming was accomplished with copper-plated blanks that were dipped in a forming lubricant or by using blanks coated with a film of colloidal graphite. The colloidal graphite is simpler to apply and less expensive.

On a 250-ton hydropress, blanks that were $10^1/_4$ in. in diameter were cold formed into hat-sections $3^1/_2$ in. deep. The machine was operated at the lowest speed—about 1 in. per sec.—to allow the material the maximum recovery time during forming. Ryan Dry-lube was used as a lubricant. The parts were drawn in four successive draws without removing them from the die.

Strips of titanium in several thicknesses—0.018 in., 0.040 in., 0.080 in., and 0.015 in.—were bent in a brake press using dies of decreasing radii, until a fracture occurred to establish minimum-bend radii for design purposes. Specimens were bent with their edges either in the sheared, milled, or polished condition. Edge preparation seemed to have no effect on results of the bend tests.

The 0.018-in. material took a 1.7T bend without fracturing. Bends in the transverse and longitudinal directions gave the same results. Minimum-bend radii for the 0.040-in. material fell over a wide range: longitudinal samples, 1.66T to 2.35T; transverse samples, 1.95T to 3.90T. Minimum-bend radii for 0.080-in. sheet covered the following range: longitudinal samples, 1.95T to 2.35T; transverse samples, 1.70T to 2.54T. For the 0.125-in. material, longitudinal samples ranged from 1.50T to 2.12T, and transverse samples 2.12T.

Fusion Welding

Experience in the study showed that inert gas shielded welding is the only type of fusion welding which can be made on titanium if it is desired to maintain adequate physical properties. This is because molten titanium will react with, and be embrittled by, all known welding fluxes as well as air. Ryan welded a substantial number of specimens with both manual and automatic inert gas shielded methods. Butt welds were successfully made in an automatic Heliarc machine, using $^1/_8$-in. diameter thoriated tungsten electrodes and a $^5/_{32}$-in. electrode distance. A copper tube with $^3/_8$-in. flare outlet was used to follow up the weld and blanket the hot metal with argon gas to prevent con-

Drop hammer and die heater setup used to evaluate titanium forming techniques. Die is heated by molten salt circulated from furnace. Punch is heated electrically.

Employees assemble shrouded exhaust systems for "buried" engines of Piasecki helicopters. Titanium shroud sections are performing well under these 500°F. applications.

tamination during cooling. On the underside of the weld a grooved back-up bar was used which blanketed the underside with argon gas. This arrangement consumed 7 cu.ft. of argon gas per hour for back-up needs and 20 cu.ft. per hour at the electrode.

Welds were made at the speed of 27 in. per min. with 65 amp. of current. Results of this work disclosed a number of factors important to good fusion welding of titanium. Many of these are not peculiar to titanium but are also encountered in the welding of stainless steels and other alloys.

Shear cuts must be straight and smooth, and fit must be close, running to within 0.001 in. on 0.016-in. material. Poor fit will cause burn-through on light gages. Best back-up is a flat copper bar. On light gages, no gas back-up is necessary if the material is tightly pressed against the copper back-up bar.

In heavy gages, an excessive gap will give a concave bead surface. A slow welding speed will cause a wide bead. Amperage has less effect upon penetration than welding speed. As gages run higher, amperage input goes up, disproportionately.

Welds of good quality, in which the welds were found to be stronger than the parent metal, were obtained. This was revealed in tensile tests in which fractures occurred outside the weld zone. The major yield was confined to one side of the weld. Failures that occurred in the weld zone initiated in small flaws within the bead. Bend tests indicated that the gas shielding provided good protection and that most welds exhibited good ductility. The welds took a 180° 3T bend in both longitudinal and transverse directions without failing.

Sigma welding was performed using 0.125-in. sheet and 0.064-in. titanium wire. Circular passes were made on one side of each sheet. The welds were found to be very sound in structure with penetrations of between 20 and 40 per cent. A 180° bend was obtained when the bend placed the bead in compression. A bend, placing the bead in tension, fractured at 45°. This fracture started at the surface of the bead. Microscopic examination of the original cracks showed them to be approximately 0.007 in. deep. This indicates that the weld bead may have a contaminated surface skin that is very hard. Such a surface would shatter under tension and create stress concentrations that would lead to failure. All discoloration from welding was removed by processing in a salt bath at 800°F. for 10 min., followed by a 20-min. immersion in a pickling solution.

Following successful butt welding of titanium by automatic Heliarc welding, a number of lap welds were made. Welds were accomplished in 0.016-in., 0.063-in., and 0.080-in. materials. They were made with manual Heliarc torches equipped with a follow-up tube of argon gas flow. Hand-fed, commercially pure titanium wire was added as a filler rod.

Static tensile test failures occurred either in the parent metal or in the weld heat-affected zone. The welds were sectioned and examined for penetration and structure. Results showed that good care is required to maintain proper root penetration.

An additional departure from the handling of stainless-steel alloys was noted. When shearing stainless steels in preparation for rolling before welding a cylindrical body, allowances are made for anticipated shrinkage in the longitudinal butt weld. The welded parts are then sized on expanding mandrels. With titanium, no shrinkage in the welded cylinder occurs, and it is often necessary to shrink the welded part to mate it with others.

Resistance Welding

A wide variety of combinations of sheet thicknesses were tested on spot-welding machines to determine the conditions favorable for spot welding titanium. Extreme thick-to-thin ratios were spot welded without difficulty. Gages running from 0.025 in. to 0.125 in. were handled. An extensive investigation of electrodes, pressures, and currents was pursued. Results showed that lower electrode pressures (800 to 2,000 lbs.) produced a coarse-grained nugget. Increasing the pressure resulted in a finer-grained structure. The transition point seemed to be at about 2,000 lbs.

At lower electrode pressures, penetration is heavy. One sample averaged 75 per cent with some cast weld stringers extending approximately 95 per cent into the parent metal, with an 800-lb. pressure. Nugget dendrites were extremely large. At 3,000 lbs. of pressure, penetration was 50 per cent maximum and 10 per cent minimum, and there was a marked refinement in dendritic structure.

During tension and shear tests, it was noted that in several cases yield points occurred at 250 to 800 lbs. After yielding, the specimens recovered and continued to failure. This was caused by the failure of the corona bond.

A typical series of shear tests showed values from 2,100 to 2,340 lbs., with a deviation of 10.6 per cent.

In general, these examinations showed that good spot welding of titanium may be achieved with proper precleaning, relatively high electrode pressures, and a short weld time. Complete certifications for a variety of gage combinations were developed.

Tests were made to determine the effect of various types of electrodes. These were conducted with Class I, II, III, and XI electrodes having $^3/_8$-in. faces and 3-in. radii. Results showed that the Class II and III electrodes produced the most satisfactory welds. Penetrations ran from 40 to 45 per cent with nugget diameters of 0.145 in. and 0.150 in. The dendrites found in these samples were finer and more uniform than those produced by the other classes.

The seam welding of titanium sheet in gages of 0.016 in., 0.025 in., 0.040 in., 0.080 in., and 0.125 in. was investigated. In general, the welding characteristics were not different from those experienced with spot welding. Complete machine settings and charts were developed to guide others.

It was found that pressure and heat should be maintained on the minimum side to prevent excessive indentation and expulsion, respectively. Speeds in the range of 15 to 20 in. per min. were found to be satisfactory. Hold times, weld times, cool times, etc., were somewhat similar to the values used with stainless steels.

Special care must be exercised to maintain penetration at a low value or it will approach 90 per cent. Small changes in machine settings will cause large increases in penetration. The standard peel test affords a quick method of determining approximate penetration. It is not as satisfactory on titanium as on stainless steel because of the brittle nature of the heat-affected zone.

Indentation is greater with titanium than with the seam welding of most materials. A difficult problem presents itself if low indentation values are required. Surface discoloration was slight on thinner gages, becoming quite heavy on the thicker material.

Embrittlement

Ryan tested the embrittlement of titanium samples by exposing them to a synthetic exhaust gas atmosphere. The specimens were sealed in a heat-resistant alloy cabinet that was purged with the gas mixture (85 per cent N_2, 11.5 per cent CO_2, and 3.5 per cent O_2) at the rate of 12 liters per hour. Tests were conducted at uniform temperatures between 1,000° and 1,400°F.

Times of exposure varied from 4 to 350 hours. Samples were suspended so that no gas impinged directly upon the parts. Results were evaluated by bend tests. Tests showed that little embrittlement occurred at 1,000°F. but that the rate increased rapidly as the temperature approached 1,400°F. Rockwell "A" hardness readings failed to show a marked increase in the hardness level, even after exposures at 1,400°F. where embrittlement was the most severe. At 1,400°F., a marked change in the adherence of oxide scale was noted. Heating to, or cooling from, this temperature caused the scale to spall off in large flakes.

Here the author conducts a tensile test of titanium at temperatures induced by electric current.

Riveting and Dimpling

First experiments with cold riveting were not successful. Using $^1/_8$-in. diameter rivets and hole diameters of 0.128 in., the rivets did not swell or spread to fill the holes when standard riveting guns and bucking bars were employed. These were button-head rivets. With flush rivets and pressures of 0 to 5,000 lbs., exerted over 1 sec., the results were good.

Similarly excellent results were obtained with $^1/_8$-in. button-head rivets that had been annealed for 20 min. at 1,300°F. and driven with a force of 5,100 lbs. Good results were achieved in the experiments with hot riveting in which $^1/_8$-in. rivets were inserted in drilled sheets of 0.072-in. and 0.018-in. material and placed in a Federal spot welder. The machine was equipped with Elkalloy-A electrodes with $^1/_8$-in. spherical-radius, counter-bored faces.

Hot dimpling was performed on both stationary and portable squeezers. Dies were heated with resistance-type elements. Dimples were formed in 0.016 in., 0.025 in., 0.040 in., 0.063 in., and 0.080 in. for a variety of rivet and screw applications running from $^3/_{32}$-in. to $^1/_4$-in. diameters. Results indicated that dimpling of titanium offers no greater problem than does 75ST aluminum, with the exception of increased forming temperatures.

Forming temperatures should be within 600° to 700°F. to produce structurally sound dimples free from critical fracture strains. Satisfactory dimples can be made at lower temperatures, but inconsistencies in sheet stock preclude its recommendation.

Ryan conducted a thorough study of other manufacturing processes involved in the fabrication of sheet-metal titanium parts—such as drilling, grinding, sawing, blanking, cleaning, and deburring—but space limitations do not permit their description in this résumé.

Allocation of Fuel and Cargo for Maximum Ton-Miles

A. N. PETROFF*
Cessna Aircraft Company

SUMMARY

Expressions are derived for allocating fuel and cargo weights to obtain maximum ton-miles for a propeller-driven and jet aircraft flying at constant and variable altitudes.

INTRODUCTION

IN THE EARLY STAGES of preliminary design of any aircraft there is a point when the designer would like to know how much space and weight should be left for the cargo and the fuel. At this stage the configuration of the aircraft is not "frozen," and reliable aerodynamic and propulsive characteristics usually are not available.

The determination of maximum ton-miles for a given initial gross weight requires a series of trial-and-error calculations involving location of points of maximums on a family of curves of ton-miles plotted against fuel weight.

The method presented here eliminates trial-and-error calculations and furnishes directly the fuel and the cargo weights for maximum ton-miles with sufficient engineering accuracy.

The component weights of an aircraft are related by

$$G = B + C + F + T \tag{1}$$

where

G = gross weight
B = basic weight
C = cargo weight
F = fuel weight
T = fuel tankage weight

G and B are given, and T/F is known for the selected type of fuel tank construction. The problem is then to find F and G for maximum ton-miles.

Eq. (1) can be written as

$$\frac{C}{G} = 1 - \frac{B}{G} - \left[1 + \frac{T}{F}\right]\frac{F}{G} \tag{2}$$

Let

$$x = F/G$$

$$K = T/F$$

$$A = [1 - (B/G)]/(1 + K)$$

Then Eq. (2) reduces to

$$C = G(1 + K)\,(A - x) \tag{3}$$

* Director, Research Department, Aircraft Division.

In preparation of this paper, the author would like to acknowledge the helpful advice of Dr. F. Butter, Mathematician, Hughes Aircraft Company.

(I) PROPELLER-DRIVEN AIRCRAFT

Breguet's equation for the range at constant altitude in terms of x is

$$R_p = N_p \cdot \ln\,[1/(1 - x)] \tag{4}$$

where

N_p = $375\,(\eta/c)\cdot(L/D)$
η = propeller efficiency
c = specific fuel consumption of a piston engine
L/D = lift to drag ratio on the airplane in cruising condition

It should be noted that N_p contains product of the propulsive and the aerodynamic efficiencies of the airplane. They are the two most elusive performance parameters, accurate determination of which requires long and tedious calculations. Fortunately, careful analysis verified by flight tests indicates that N_p, for all practical purposes, can be considered constant, and it is treated as such in the following analysis.

Multiplying Eqs. (3) and (4) to obtain the quantity $C \cdot R_p$, which is ton-miles, we write

$$C \cdot R_p = N_p G(1 + K) f(x) \tag{5}$$

where

$$f(x) = (x - A)\,\ln\,(1 - x) \tag{6}$$

The problem then is to find x to maximize $C \cdot R_p$ or, equivalently, $f(x)$. To this end, Eq. (6) is differentiated with respect to x and equated to zero:

$$f'(x) = -[(x - A)/(1 - x)] + \ln\,(1 - x) = 0$$

whence

$$A = x - (1 - x)\,\ln\,(1 - x) \tag{7}$$

Since Eq. (7) is transcendental in x, it is necessary to resort to a graphical solution. Fig. 1 presents the plot of A against x covering the useful range of x. Knowing x for a given A, the corresponding C is obtained from Eq. (3).

(II) JET-DRIVEN AIRCRAFT

Breguet's equation for the range at constant altitude can be written in terms of x as

$$R_j = N_j \sqrt{G}\,(1 - \sqrt{1 - x}) \tag{8}$$

where

N_j = $(1.929 C_L^{1/2})/(c' \sqrt{\rho S}\, C_D)$
c' = specific fuel consumption of a jet engine
S = wing area in sq.ft.

The product of Eq. (3) and Eq. (8) gives

$$C \cdot R_j = N_j G^{3/2}(1 + K) f(x) \tag{9}$$

where

$$f(x) = (A - x)\,(1 - \sqrt{1 - x}) \tag{10}$$

As before, differentiating Eq. (10) with respect to x and equating to zero:

$$f'(x) = 1\ 2(A - x)\,(1 - x)^{-1/2} - [1 - (1 - x)^{1/2}] = 0 \tag{11}$$

Rationalization of Eq. (11) leads to the quadratic

$$9x^2 - 2(3A + 4)x + A(A + 4) = 0 \tag{12}$$

of which the solution is

$$x = (3A + 4 - 2\sqrt{4 - 3A})/9 \tag{13}$$

Knowing x for a given A, the corresponding C can be obtained for Eq. (3). The plot of A against x is included in Fig. 1.

The method can be extended to flight at variable altitude, when the aircraft is climbing as fuel is being used.

(*a*) *Altitude below 35,000 ft.:*

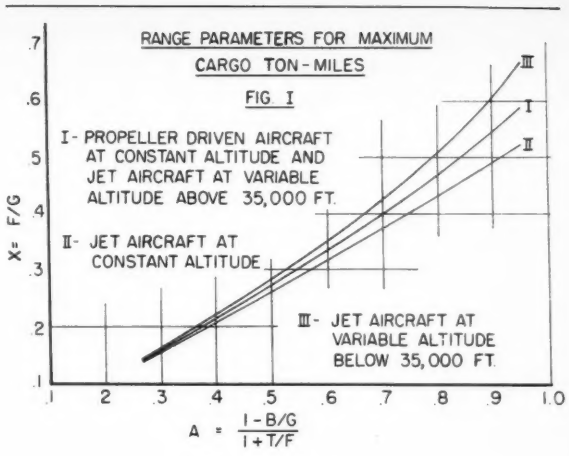
The equation for range takes the following form:

$$R_{j_1} = N_{j_1} \frac{1}{\sqrt{G}} \left(\frac{1 - \sqrt{1 - x}}{\sqrt{1 - x}} \right) \tag{14}$$

where N_{j_1} is a constant co..taining the propulsive and the aerodynamic efficiency of the aircraft. (See reference 1, Eq. 7.)

The product of Eqs. (14) and (3) gives

$$CR_{j_1} = N_{j_1} G(1 + K) \frac{(A - x)\,(1 - \sqrt{1 - x})}{\sqrt{1 - x}} \tag{15}$$


RANGE PARAMETERS FOR MAXIMUM
CARGO TON-MILES
FIG I
I- PROPELLER DRIVEN AIRCRAFT AT CONSTANT ALTITUDE AND JET AIRCRAFT AT VARIABLE ALTITUDE ABOVE 35,000 FT.
II- JET AIRCRAFT AT CONSTANT ALTITUDE
III- JET AIRCRAFT AT VARIABLE ALTITUDE BELOW 35,000 FT.
X= F/G
A = I - B/G / I + T/F
I
II
III

As before, maximizing and solving for A,

$$A = 2 - x - 2(1 - x)^{5/2} \tag{16}$$

(*b*) *Altitude above 35,000 ft.:*

The equation for the range is

$$R_{j_2} = N_{j_2} \ln \left(\frac{1}{1 - x} \right) \tag{17}$$

(See reference 1, Eq. 11.)

In this case, since Eqs. (17) and (4) contain the identical function of x, it follows that the optimum allocation of fuel and cargo for the propeller-driven aircraft at constant altitude and for the jet aircraft at variable altitude above 35,000 ft. are the same.

Reference

[1] Ashkenas, I. L., *Range Performance of Turbo Jet Airplanes*, Journal of the Aeronautical Sciences, Vol. 15, No. 2, pp. 97–101, February, 1948.

Last Call for Roster Listing

All members are reminded to send in their completed Roster Data Cards if they wish to change their listing in the next edition of the Roster. Members whose names do not appear in the 1954–1955 Roster are especially urged to return their cards immediately.

Those members not returning the data cards will be listed by repeating the entry that appeared for them in last year's Roster. This is your last opportunity to be correctly listed in the 1955–1956 IAS Roster.

IAS News

(*Continued from page 29*)

▸ **Leo A. Weiss** (TM), President, Avien, Inc., is serving as Chairman of the Aircraft Manufacturers Division of the 1955 Greater New York Campaign of the National Foundation for Infantile Paralysis.

▸ **George W. Westphal** (M), Preliminary Design Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation, is serving as a member of the 1955 Air Cargo Advisory Committee, National Security Industrial Association.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

John A. Bachman, Jr. (TM), Aerodynamist, Comprehensive Designers, Inc. Formerly, Aerodynamist, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation.

J. E. Barfoot (AF), Project Engineer—Structures, KC-135 Jet Tanker Program, Boeing Airplane Company. Formerly, Engineering Manager, Moses Lake Flight Center, Boeing.

William O. Boschen (AM), Vice-President—Sales, Avien, Inc. Formerly, Director—Sales, Avien.

W. V. Boughton (AF), Chief Electrical and Electronic Systems Design Engineer, Republic Aviation Corporation. Formerly, Vice-President, Nader Engineering Company and Motordyne, Inc.

Goosen Broersma (M), Chief Engineer, Gear Reduction Factory and Foundry, Royal Shipbuilding and Engineering Company "De Schelde," Flushing, the Netherlands. Formerly, Adviser, Royal Dutch Airlines, the Netherlands.

Colonel Robert J. Benford, USAF (MC), AFIAS, was named Editor of the Aero Medical Association's official publication, *The Journal of Aviation Medicine*. Colonel Benford, a native of Omaha, Neb., and a University of Nebraska School of Medicine graduate, was appointed the first USAF Editor of the *U.S. Armed Forces Medical Journal* on July 1, 1953.

Kenneth Campbell (F), Manager, Research Division, Curtiss-Wright Corporation. Formerly, Technical Director, Wright Aeronautical Division, Curtiss-Wright.

Frank Conace (M), Sales Manager, Aeronautical Equipment Division, Sperry Gyroscope Company Division of The Sperry Corporation. Formerly, Director, Field Service Engineering, Sperry.

John Cory (TM), Test and Development Engineer, Development Design, Engineering Division, Chrysler Corporation. Formerly, Special Products Engineer, Automotive Engineering Department, Ford Motor Company of Canada, Ltd.

Corwin D. Denney (M), President, Mid-Continent Manufacturing, Inc. Formerly, General Manager, American Helicopter Division, Fairchild Engine and Airplane Corporation.

Bruce G. Eaton, Jr. (AF), Senior Advisory Engineer, Air Arm Division, Westinghouse Electric Corporation. Formerly, Technical Director, Special Devices Center, Office of Naval Research, Port Washington, L.I., N.Y.

Percy Halpert (AF), Engineering Director, Aeronautical Equipment, Sperry Gyroscope Company Division of The Sperry Corporation. Formerly, Department Head, Flight Control Engineering, Sperry Gyroscope.

Spencer Kellogg II (M), Engineering Manager, Aeronautical Equipment Division, Sperry Gyroscope Company Division of The Sperry Corporation. Formerly, Department Head, Flight Instrument Engineering, Sperry.

Colonel Howard M. McCoy, USAF (Ret.), Manager, New Internal-Security Equipment Development Program, The Gray Manufacturing Company. Formerly, on active duty, USAF, as Director, Physical Security Equipment Agency, Department of Defense.

Joseph V. Miccio (AM), Vice-President and General Manager, Wright Aeronautical Division, Curtiss-Wright Corporation. Formerly, Vice-President and Executive Assistant General Manager, Wright Aeronautical Division, Curtiss-Wright.

Norman R. Oxhorn (TM), Communications Engineer, Grumman Aircraft Engineering Corporation. Formerly, Designer, Sikorsky Aircraft Division, United Aircraft Corporation.

A. L. Paquette (M), Manager, Aircraft Field Sales, Small Motor Division, Westinghouse Electric Corporation. Formerly, Manager, Aviation Sales, Central District, Westinghouse.

J. S. Parker (M), General Manager, Aircraft Gas Turbine Division, General Electric Company. Formerly, Manager, Small Aircraft Engine Department, G-E.

Edward M. Powers (F), Vice-President—Engineering and Research, Curtiss-Wright Corporation. Formerly, Vice-President and General Manager, Wright Aeronautical Division, Curtiss-Wright.

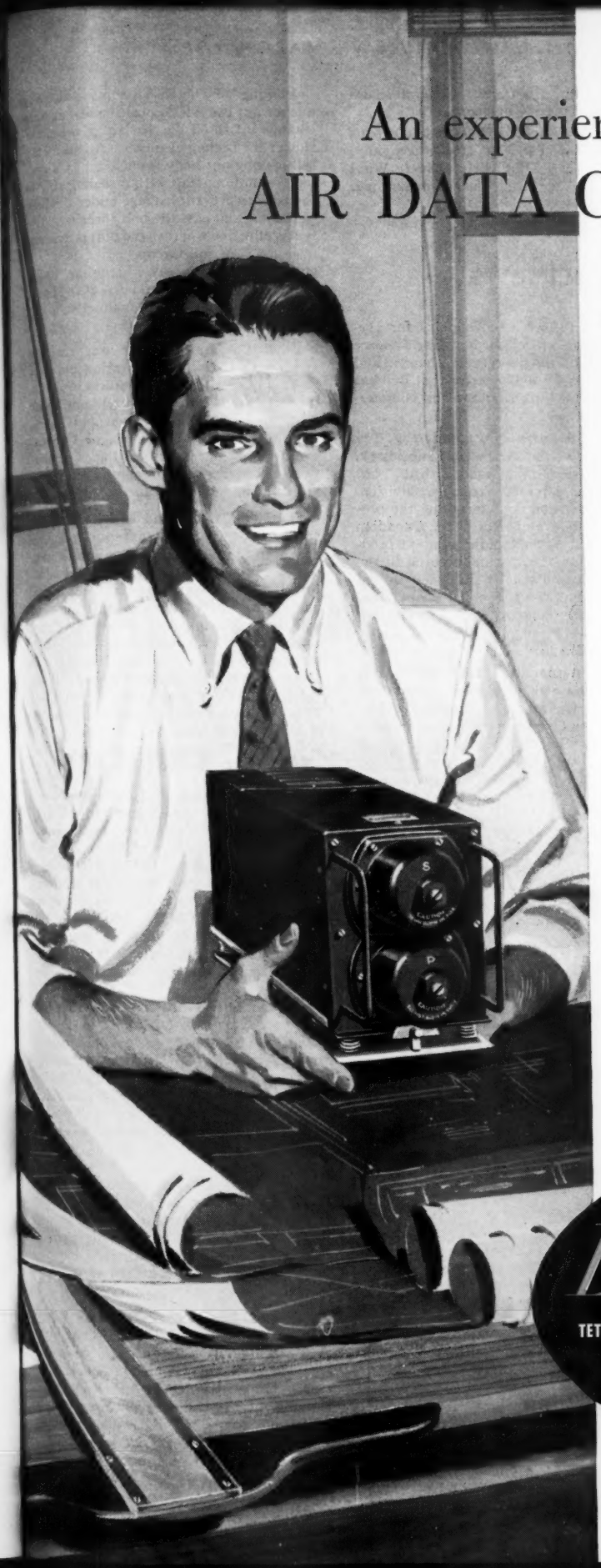
John M. Schuler (TM), Associate Engineer, Flight Research Department, Cornell Aeronautical Laboratory, Inc. Formerly, Aerodynamicist, Aerodynamics Section, El Segundo Division, Douglas Aircraft Company, Inc.

James R. Throop (TM), Lieutenant (j.g.), USN, Student Naval Aviator, Advanced Flight Training, NAAS, Kingsville, Tex. Formerly, Ensign, USN, Student Naval Aviator, Pensacola, Fla.

Lieutenant Commander Donald P. Walker, USN (M), Student Officer, Test Pilot Training School, Naval Air Test Center, Patuxent River, Md. Formerly, Operations Officer, Air Antisubmarine Sq. 26 (VS-26), Atlantic Fleet, U.S. Navy.

Maurice A. Walter (M), Research Engineer "A," Research Laboratory, Missile Systems Division, Lockheed Aircraft

Frank W. Caldwell *(left)*, IAS Honorary Fellow and Past-President, retired on December 31, 1954, as United Aircraft Corporation's Director of Research. He was succeeded in this post by John G. Lee *(right)*, FIAS, who had been Assistant Director of Research for the company since 1939. Mr. Caldwell continues to serve the company in an independent capacity as an engineering consultant.



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Corporation. Formerly, Group Engineer, Electro-Mechanical Department, The Glenn L. Martin Company.

Arthur R. Weckel (M), Vice-President and General Sales Manager, Sperry Gyroscope Company Division of The Sperry Corporation. Formerly, General Sales Manager, Sperry Gyroscope.

Philip J. Wingham (M), with Weapons Research Division, A. V. Roe & Company, Ltd., England. Formerly, Chief, Wind Tunnel Department, Vickers-Armstrong, Ltd., England.

Corporate Member News

• **AiResearch Manufacturing Company, Division of The Garrett Corporation . . .** A new electrical actuator that weighs 1.16 lbs.—as against the 2.2 of the company's 1953 model—has been developed. Its width is 1.25 in., and its height is 2.73 in. (the 1953 model measured 1.9 in. wide by 3.73 in. high). AiResearch engineers suggest such uses for the linear actuator as trim tabs, artificial feel controls, or other applications where light-to-medium loads are encountered and where space is at a premium. The company says that all design improvements of previous AiResearch actuators have been retained, including nonjamming jackscrews, limit switches, built-in radio noise filters, and magnetic brakes.

• **Aluminum Company of America . .** A 100-in. cold mill is now being constructed at Alcoa's Davenport Works. This mill, which is expected to be in operation early in 1956, is for finish rolling wide aluminum coiled sheet, used extensively in aluminum-clad buildings as well as in the aircraft and other transportation industries. . . . An illustrated eight-page booklet that describes Alcoa Aluminum Fasteners and screw machine products is now available from the company's Pittsburgh office.

• **American Non-Gran Bronze Company . . .** Statistical quality control methods have been incorporated as a part of the company's production and inspection operations. This enables the company "to determine what a manufacturing process will deliver at the beginning of the run" and "to set up the necessary controls to allow for such factors as tool wear, operator fatigue, and variations in raw material."

• **Avien, Inc. . . .** William O. Boschen, AMIAS, has been elected Vice-President—Sales; Everett M. Patterson, Vice-President—Engineering and Manufacturing; and H. Hawley Myers, Vice-President and Treasurer.

• **Bell Aircraft Corporation . . .** Hydraulic Research and Manufacturing Company, of Burbank, Calif., was acquired by Bell through an exchange of stock. This company has been developing and producing small lightweight high-pressure hydraulic valves principally for aircraft applications, including landing gear systems, control circuits, and brakes. Bell's plans for Hydraulic Research call for its being a source of production for the servomechanical and hydraulic valves and systems that Bell has developed for both military and commercial application.

• **Bendix Aviation Corporation . . .** The corporation's wholly owned subsidiary, Bendix-Eclipse of Canada, Ltd., has formed the Aircraft Products Division. This new division is undertaking the production and development of the Canadian market for certain Bendix aviation products that have been manufactured in the corporation's divisions in the United States. Pending the opening of operating facilities, the new division is occupying offices at 2444 Bloor St., West, Toronto, Ontario, Canada.

• **Cornell Aeronautical Laboratory, Inc. . . .** The new $600,000-plus continuous-flow, vertical-return, variable-density, transonic-supersonic wind tunnel has been completed. The test section of the new tunnel is 1 sq.ft. The tunnel itself is 46 ft. long and 15 ft. high. The speed range of the new facility is from Mach Number 0.8 to 2.8.

• **Curtiss-Wright Corporation . . .** The corporation has announced that its engineering program for 1955 is the largest in its history. This expanded program will be under the direction of Edward M. Powers, FIAS, Vice-President of the corporation in charge of Engineering and Research. . . . The corporation is marketing a new line of ultrasonic equipment, useful in the fields of quality control, manufacturing, food processing, and industrial and scientific research. Currently, seven newly designed units are being offered: three for manufacturing and experimental work, two for quality control, and two others for the food field. . . . Three additional simulator types are being engineered and built for the U.S. Air Force by the company's Electronics Division. These simulators will reproduce the flight characteristics of the Douglas C-118A, the Lockheed C-121D, and the Convair C-131.

• **Elastic Stop Nut Corporation of America . . .** A new self-sealing anchor nut, ESNA type A2500, was designed to seal against liquid leakage in aircraft fuel tanks in a "wet wing." The ESNA cap seal floating anchor nut provides a positive seal against leakage up to 50 lbs. per sq.in. on either side of the sealing element. An all-metal, self-locking nut body is enclosed by a one-piece aluminum cap with a sealing ring in the base to prevent leakage under the base of the nut and past the bolt threads. The seal is effective whether the bolt is or is not installed. A full-thread series is available, the company says, including 10-32, $^1/_4$-28, $^9/_{16}$-24, $^3/_8$-24, and $^7/_{16}$-20. These can be supplied in gang-channel strips as well as individual nut plates.

• **Ethyl Corporation . . .** It was recently announced that the corporation plans to build a plant at Sarnia, Ontario, Canada, for the manufacture of "Ethyl" antiknock compounds. This plant, owned and operated by Ethyl Corporation of Canada, Limited, a subsidiary of Ethyl Corporation, will be the first to manufacture antiknock compounds in Canada.

• **Fairchild Camera and Instrument Corporation . . .** A new 24,000-sq.ft. plant is being built in Los Angeles and is scheduled for completion in April, 1955. An additional 24,000 sq.ft. will be constructed at a later date. Although this new building will make possible the extension of the corporation's manufacturing, sales, and service activities, its primary function will be to expand the manufacturing facilities of Fairchild's Potentiometer Division. This new construction is located on 6 acres of land recently acquired by Fairchild at Washington Blvd. adjacent to the Santa Ana Freeway.

• **Fairchild Engine and Airplane Corporation . . .** The one-thousandth C-119 Flying Boxcar was rolled out of the Fairchild Aircraft Division plant at Hagerstown, Md., on December 16. This brings to more than 1,200 the number of military and cargo transports produced at this plant since V-E Day in 1945. . . . The Reinforced Plastics Department of the Fairchild Guided Missiles Division is being expanded and is occupying a newly leased plant at Copiague, which is near Wyandanch, L.I., N.Y.—the location of the missiles division. This new facility is to be devoted primarily to the design and production of reinforced plastic articles, including missile components. . . . The military business of Kendall Controls Corporation, Waltham, Mass., manufacturers of pneumatic valves and control devices, was purchased by Fairchild. The operations have been integrated with those of Fairchild's Stratos Division. The portion of Kendall's business purchased by Fairchild includes military rights to a group of pneumatic controls and valves developed jointly by Kendall and Stratos and a number of basic Kendall patents as well as specific controls and valves.

• **Fairchild Engine and Airplane Corporation and General Electric Company . . .** According to a recent Air Research and Development Command announcement, competitive development contracts have been let to the Fairchild Engine Division and to the Small Engine Department of G-E's Aircraft Gas Turbine Division for the development of a new small turbojet engine to be used in drone and pilotless aircraft.

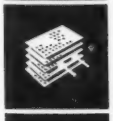
Aero Medical Association
Twenty-Sixth Annual Meeting

General Chairman
Robert J. Benford, M.D.
Colonel, USAF (MC)

March 21-23, 1955
Hotel Statler
Washington, D.C.

1 *gas turbine combustion systems*

2 *gas turbine accessories*

3  *heat exchangers*

4 *inert gas generators*

5 *deaerating oil tanks*

6 *high pressure regulators*

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If your projects involve increasing jet aircraft performance—to boost power without dry loss, to eliminate hot spots and thus achieve higher combustion rates, to develop new heat exchanger configurations—a call to Janitrol will give you a head start. Janitrol's specialized research and experience in combustion phenomena go back 50 years, and have resulted in such important developments as the Post-Turbine burner, automatic inert gas generators for inerting fuel cells, and the waffle plate principle of heat exchanger construction which improves heat transfer efficiencies and saves weight by getting the most out of metals.

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• **General Electric Company** . . . A thrust spoiler for J47 jet engines was under development for some time and about the first of this year successfully completed its full-scale engine testing. It was designed by the Aircraft Gas Turbine Division for possible future application on the Boeing B-47 Stratojet. In addition to the thrust spoiler, G-E is also working on a thrust reverser. The reverser is not presently contemplated for the B-47; however, it has been successfully tested for some installations to over 35 per cent reverse thrust of the dry military rating of the J47. . . . The Aircraft Gas Turbine Development Department announced that an option had been taken by G-E on 4,500-plus acres of land in Adams County, Ohio, near the city of Peebles. The purpose of acquiring this property is the testing of advanced models of jet engines and components—e.g., jet engines for VTO aircraft and engines equipped with thrust reversers. G-E is not exercising this option until tests on such items as water availability and soil conditions prove the land to be satisfactory. . . . A grant has been given to Columbia University for the establishment of a professorship in electrical engineering. The professorship will be used for teaching and conducting research in the fundamentals of generating, handling, and processing energy.

• **The B. F. Goodrich Company** . . . Electrically heated rubber "boots" have been developed to warm the rotor blades of a helicopter and to prevent icing. These Goodrich-developed anti-icers, which have been installed on a Bell helicopter, fit snugly along practically the entire length of the rotor blades. Helicopters so equipped are said to be capable of performing in sub-zero conditions.

• **Lear Incorporated** . . . The LearCal Division has developed a new 800-channel VHF transmitter-receiver, Model LTR-800, for use in either single- or multi-engined executive aircraft and in military aircraft. The frequency coverage provides utilization of all VHF communications channels available in the United States and in foreign countries. First production models of the LTR-800 are expected about mid-1955. . . . A new linear actuator has been developed for aircraft applications in which weight and envelope size restrictions are important factors. The Series 413 units weigh between 1.7 and 2.4 lbs. In both tension and compression, the company says, they provide "ultimate structural strength up to 2,000 lbs., maximum static strength up to 1,300 lbs., and operating output up to 500 lbs." Envelope size of the largest actuator is $1^{7}/_{8}$ by $3^{3}/_{4}$ in. with an overall retracted length of $7^{1}/_{2}$ in. Maximum stroke is 3 in. Applications include the actuation of trim tabs in jet aircraft, fuel dump valves, and mechanical-advantage shifters. . . . The Learstar's improved main landing gear wheel and brake system for installation on all Lodestars is now available in kit form, the corporation's Aircraft Engineering Division recently announced. The complete conversion kit includes new wheels, brakes, special parts, all necessary AN hardware, and installation drawings; it does not, however, include tires and tubes. . . . Lear announced it has pur-

A USAF fighter is shown blasting off a zero-length launcher. This launching technique was developed by the USAF's Air Research and Development Command and The Glenn L. Martin Company. Note booster bottle attached to undersurface of the fighter's tail. (See Martin item on this page.)

chased the design and manufacturing rights to all the hydraulic and pneumatic servo systems and components of Auto-Control Laboratories of Alhambra, Calif. The products include advanced types of high-performance, high-precision servo-valves, as well as torque motors to drive the valves.

• **Lockheed Aircraft Corporation . . .** The Missile Systems Division's $4,000,000 research laboratories building is being constructed at Van Nuys, Calif. This four-story, 74,000-sq.ft. main laboratory building, the first of four similar structures included in a $10,000,000 master development program, is scheduled for completion next fall. The scope of the research center's activities is said to extend far beyond its immediate objectives of design, development, and manufacture of pilotless aircraft, guided missiles, and their systems.

• **The Glenn L. Martin Company . . .** The recently unveiled XP6M-1 SeaMaster, the U.S. Navy-Martin multijet attack seaplane, was designed for two primary missions—minelaying and photo-reconnaissance. The hull of the SeaMaster has a watertight rotary mine door on which mine stores or a camera pod can be installed interchangeably. The seaplane is powered by four afterburner-equipped Allison J-71 turbojet engines that are mounted in two sets of engine nacelles atop the aircraft's sharply sweptback wings. The XP6M-1 SeaMaster is said to be in the over-600-m.p.h. class and to cruise normally at 40,000 ft. It carries a crew of five—pilot, copilot, navigator-minelayer, radio operator, and armament defense operator. The company announced that a portable dock for use in servicing the plane while it is afloat is now being produced at Martin. This dock, which eliminates beaching, can be knocked down for storage aboard ship and can be transported by air. . . . A way of launching piloted jet fighter planes like guided missiles has been developed by the USAF's Air Research and Development Command and Martin. This launching technique employs the same principle and equipment used in launching the Matador guided missile. Tests are being run at Edwards AFB with F-84G Thunderjets being launched from Martin's zero-length launcher. The Thunderjets are modified to accommodate booster bottles beneath their tails. See Martin-ARDC picture on this page.

• **Minneapolis-Honeywell Regulator Company . . .** A tiny resistor that is ten times more sensitive to temperature change than "any metallic conductor" is being used as the detecting element in a new liquid-level switch now being volume produced by the company's Aeronautical Division. These negative-temperature coefficient resistors, called thermistors, are available from pinpoint size upward, in various resistance values, and in bead, disc, washer, rod, flake, and printed patterns. . . . A new aircraft engineering center has been established in Los Angeles by the company's Aeronautical Division. This facility, occupying 20,000 sq.ft. of floor space in a new building at 1915 Armacost Ave., West Los Angeles, was said by a division official to be necessary "to fulfill expanded military development and engineering commitments in the field of guided missiles and complex aircraft control systems."

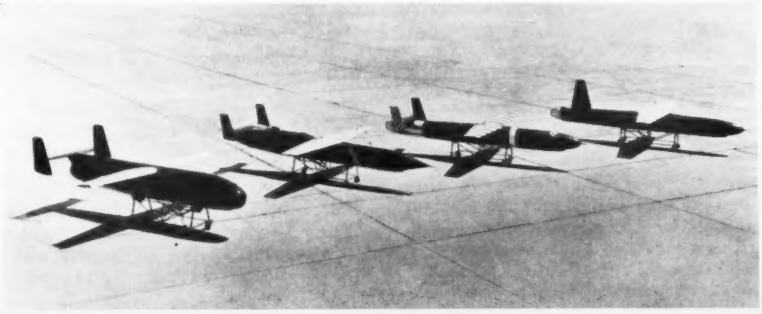
• **Northrop Aircraft, Inc. . . .** The largest Dy-Chek inspection facility in the nation—it occupies 3,750 sq.ft.—has been installed at the Hawthorne factory for production-line inspection of major components of the F-89D Scorpion and the XB-62 Snark. Although the Dy-Chek process can be applied to both ferrous and nonferrous metals, Northrop is using it at present only on ferrous metals, including aluminum and magnesium parts. A dye-penetrant method of inspection, Dy-Chek was originally developed by Northrop several years ago and is now being manufactured by Turco Products, Inc., under an exclusive license from Northrop.

• **Piasecki Helicopter Corporation . . .** The HUP-4, an HUP-2 fleet helicopter powered by a more powerful engine—the Wright R-1300-3, made its first flight on December 31. The flight was the first phase of a two-part program sponsored by the Navy's BuAer to increase performance of its present fleet helicopter. The HUP-4 design is such that retrofit installation can be incorporated in the HUP-2, H-25A, and HUP-3 to convert them to the new higher performing version.

• **Republic Aviation Corporation . . .** The RF-84F Thunderflash is now being delivered to USAF operational units. This Air Force fighter, developed for photo-reconnaissance work, is also used in Project FICON. In FICON, a Thunderflash "takes off" and "lands" in mid-air from a GRB-36 aerial carrier plane. Planes modified for FICON can be operated either as separate units with normal take-off and landing or as a composite for global reconnaissance missions. . . . John A. Thompson was elected Secretary of the corporation. Mr. Thompson has been and will continue as Assistant Counsel at Republic.

• **Shell Oil Company . . .** Contracts for over $2,000,000 have been signed by Shell and Pratt & Whitney. Under the terms of these contracts, Shell supplies Pratt &

The step-by-step development of the YQ-1B jet-propelled pilotless aircraft built by Radioplane Company, a subsidiary of Northrop Aircraft, Inc., is shown. From *left to right* are: the YQ-1B turbojet-propelled drone, first flown in 1953; its predecessor, the XQ-1A turbojet-propelled drone, first flown in 1952; the XQ-1 (Modified) pulse-jet-propelled drone, first flown in 1951; and the first in the development series, the XQ-1 pulse-jet-propelled drone, first flown in 1950. A parachute carried within the fuselage is released on command at the conclusion of a radio-controlled flight, thus permitting recovery of the drone. This parachute recovery system was developed by Radioplane.



Herbert C. Bostwick, MIAS, has been named Manager of the recently formed Aeronautical Equipment Division of Sperry Gyroscope Company Division of The Sperry Corporation. Mr. Bostwick was formerly Sperry's Engineering Director for Flight Research.

Whitney with all piston engine oil (Aero-Shell Oil 100) and one-half the jet propulsion fuel (JP-4) required during 1955. . . . A four-year contract to supply kerosene for Capital Airlines' turboprop Viscounts, scheduled to go into service this spring, has been awarded to Shell.

• **Socony-Vacuum Oil Company, Inc. . . .** Trans-Canada Air Lines has awarded Socony-Vacuum a contract to supply JP-4 fuel oil when its new turboprop Viscounts go into service between New York International Airport (Idlewild) and Montreal.

• **Solar Aircraft Company . . .** Stainless Alloy Foundry was sold by Solar to a recently formed affiliated corporation, Pacific Alloy Engineering Corporation, of El Cajon, Calif. It was said by a company official that Solar decided to sell the foundry operation to provide more space in the San Diego plant for expanded programs involving the manufacture of gas-turbine engines and other company developments. . . . Herbert Kunzel, a Director, has been elected Executive Vice-President. He was formerly Vice-President, Secretary, and Manager of the San Diego plant.

• **Sperry Gyroscope Company Division of The Sperry Corporation . . .** Three Vice-Presidents were recently elected at Sperry Gyroscope. They are Edward E. Daparma, formerly Director of Industrial Relations, who was appointed Vice-President for Industrial Relations; George A. Richroath, formerly Works Manager, who was named Vice-President and Works Manager; and Arthur R. Weckel, MIAS, General Sales Manager since 1950, who was made Vice-President and General Sales Manager.

• **United States Rubber Company . . .** In a series of tests to develop crash-resistant fuel cells for commercial airplanes, U.S. Rubber's Fuel Cell Department has been cooperating with the CAA Technical Development and Evaluation Center at Indianapolis, Ind. U.S. Rubber has been supplying test materials to the technical center since 1949; these materials have ranged from full-sized fuel cells for catapult crash tests to circular panels, about 36 in. in diameter, for burst tests on a large compressed-air gun. The tests conducted on these materials resulted in four of them being selected for the full-sized bladder cells used in the final phase of the testing program.

• **Western Gear Works . . .** The company has announced a new horizontal stabilizer actuator unit for aircraft application. This precision-built stabilizer drive mounts both 110-volt a.c. 400-cycle and 24-volt d.c. motors for optional operation, providing three speeds for manual, autopilot, and coarse control. . . . The machinery required for the conversion of a U.S. Naval vessel to a cable-laying ship is being designed and manufactured by Western Gear. The $1,000,000 contract covers the design, manufacture, and assistance in the installation of the "largest and most precise type of submarine cable-laying machinery ever developed."

• **Westinghouse Electric Corporation . . .** Production on an $18,700,000 order for aviation tail turret defense systems will begin this summer. This equipment, ordered by the USN BuAer, is to be part of the defense systems for the Douglas A3D Skywarrior attack plane. . . . New jet-engine research and development facilities are to be built on the site of the jet-engine plant south of Kansas City, Mo. The new facilities, to cost more than $12,500,000, will include both high- and low-power laboratories and an experimental engineering shop. The laboratories will provide for research and development testing on components of new jet-engine designs and for development of improvements in existing jet engines. The experimental shop will manufacture newly designed components, as well as complete experimental engine models. The entire operation will be a part of the Engineering Department of the Westinghouse Aviation Gas Turbine Division and will come under the supervision of Allan Chilton, FIAS, Chief Engineer of the division.

Meet Your Section Chairman

Edward M. Flesh

St. Louis Section

Bud Flesh, a native of St. Louis, has had 24 years' experience in the aircraft industry, all of which were obtained with St. Louis firms, Curtiss-Wright Corporation and McDonnell Aircraft Corporation.

He attended the University of Missouri and obtained a degree in Mechanical Engineering in 1929. While in college, Bud displayed a great interest in aviation. During his summer vacations, he sold sight-seeing trips for the famous Jackson-O'Brien endurance team in exchange for flying lessons.

In 1929, Bud was employed by Curtiss-Wright as a Layout Draftsman on the Curtiss Robin, the airplane in which he received his instruction and made his first solo flight. Within a year, Bud was transferred to the Curtiss plant in Buffalo where he worked as a Stress Analyst.

When he returned to St. Louis in 1931, he was promoted to the position of Group Leader on the Curtiss Condor. He held this position until 1937, when he became Assistant Project Engineer on the Curtiss Model 21B, an interceptor built for export. In 1939, Bud was made Project Engineer on the SNC-1, a Navy trainer. Following this assignment, he supervised the design of the XP-55, an advanced Air Force interceptor; the XC-113, a turboprop installation in a C-46; and the XF-87, an experimental all-weather fighter.

Bud went to McDonnell in 1946 and was made Project Engineer first on the XF-88 Voodoo and later on the XF-88B turboprop version. His current assignment is that of Project Engineer on the F-101, the Air Force's latest high-performance fighter.

Bud's technical abilities are supplemented by a heretofore unpublicized, amazing talent for song-writing. His latest hit, "The Voodoo Serenade," is being played and sung in the more important circles these days.

Bud and his wife, Dorothy, are the parents of two girls—Barbara, 17, and Susan, 13. They reside in University City, Mo.

ALLEN H. MADRICK
Chairman, Publicity Committee
St. Louis Section

RESEARCH KEEPS **B.F.Goodrich** FIRST IN RUBBER

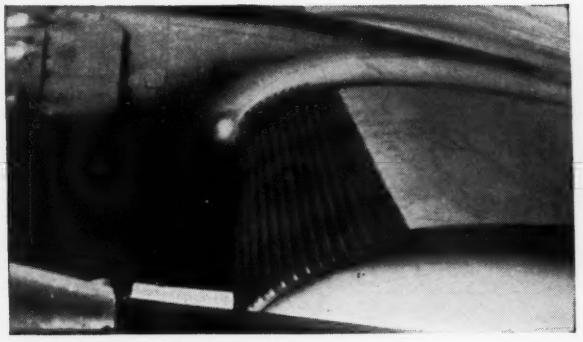
How to keep planes from coming down with the cold

KEEPS ICE FROM CHOKING A PLANE'S THROAT

Ice forming in the narrow "throat" of an engine intake could soon choke off vital air supply. B. F. Goodrich electrically heated rubber—rubber with resistance wires in it like a heating pad—prevents ice from forming. Its flexibility lets it fit skin-tight around the intake's bulges, curves and corners. BFG heated rubber also gives cold weather protection on propeller blades, spinner domes, hydraulic lines, many other parts.

EGG BEATER WHIPS ICE

The weight of ice forming on rotor blades used to ground helicopters in cold weather. The problem was to design an anti-icing system that wouldn't add as much weight as the ice. B. F. Goodrich engineers developed a set of specially shaped heated rubber boots that minimized weight and bulk. 30-day tests in freezing rain and snow, down to −14°F, proved their worth. The biggest single obstacle to all-weather helicopter operation was removed.



MAKES ICE REMOVING A SNAP

This B. F. Goodrich De-Icer has rubber tubes that inflate to crack ice off wing leading edges. B. F. Goodrich De-Icers have been giving planes ice protection since 1930. Latest type De-Icers snap off ice faster by inflating quicker with almost three times the pressure of earlier models. They last longer, too, because they're simply cemented to the wing without stretching or fixed tension.

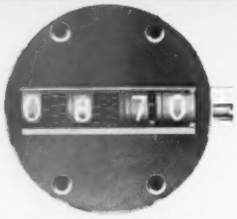
RUBBER BOOTS HELP BUSINESSMEN HURRY

"We can count on B. F. Goodrich De-Icers to keep wings of our plane ice-free," say flight personnel of the Hoover Company. "They enable us to make trips we otherwise couldn't make." Practically every executive plane of twin-engine size or larger has De-Icer plumbing already built-in, making the cost of De-Icer installation low-cost insurance.

For 25 years, B. F. Goodrich engineers have been solving aircraft icing problems of all kinds. Why not let them put this background of experience to work for you? Write *The B. F. Goodrich Company, Aeronautical Sales, Akron, Ohio.*

B.F.Goodrich
FIRST IN RUBBER

Both the Counter and the Dial Indicator are shown full size.



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The Kearfott Counter shown can be read with the same ease and accuracy as a dial indicator 143 inches in diameter.

Ball Bearings and precision hardened steel parts used in Kearfott Counters permit their high speed rotation for long periods of time. Kearfott Counters are capable of being driven at 1800 RPM. Precision parts also contribute to precise positioning and precise reading.

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DECIMAL COUNTERS: High speed decimal count from 0-9999 and return to 0 in ½ increments. Maximum speed 1800 RPM. One revolution of shaft equals 10 units.

LONGITUDE COUNTERS: For east-west longitude indication in degrees and minutes in ½ minute increments. Mask transfers hemispheric indication at 0° and 179°59'. Maximum speed 1800 RPM.

LATITUDE COUNTERS: Indicates N 89°59' to S 89°59'. For same direction of input the mask transfers hemispheric indication and reverses reading at 00 degrees 00 minutes. Maximum speed 1800 RPM.

Variations of these Standard Types are available for special purposes.

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IAS Sections

Atlanta Section

Edith Hall Lively, *Secretary*

The IAS Atlanta Section combined its November and December meetings by coming together on Thursday evening, December 2, at the Officers' Club at the Chamblee, Ga., Naval Air Station. A social hour preceded the dinner and meeting. A formal business session was dispatched quickly by Chairman E. I. Bricker. Program Chairman Otis Norcross introduced the guest speaker, Robert D. Roche, one of Lockheed's Georgia Division Military Operations Research Engineers serving as Staff Meteorologist.

Mr. Roche is not only a graduate in chemistry but a researcher in the field of meteorology. He served with the USAF Air Weather Service, later becoming Research Meteorologist for Eastern Air Lines, Inc. He holds a CAA Commercial Pilot Certificate with an Instrument Rating. For a time, he was a civilian Instructor in Meteorology with the U.S. Army. Mr. Roche gave an illuminating and illustrated lecture on "The Jet Stream."

The discovery of the jet stream was attributed to World War II high-altitude pilots who provided enough upper wind information to confirm the existence of these narrow rivers of high-velocity winds that meander through the relatively quiescent high tropospheric air. The general characteristics of the jet stream were outlined and described with slides.

The lecture went into some detail on the jet stream structure by touching upon the associated thermal and wind fields. Numerous cross sections made clear the structure features. One of the more interesting points brought out was the striking analogy from the point of structure between jet streams and major ocean currents.

The significance of the jet stream to aeronautics was outlined. The discussion took in the problem of wind-air to flight as well as that of locating jet streams while air borne by identification of cloud formations and by thermal gradient features.

Mr. Roche closed his remarks by briefly indicating the tremendous import of the jet stream to the science of meteorology along the lines of contribution to general circulation theorems, to weather predictions, and to other related scientific fields, especially the aeronautical sciences.

Dayton Section

Gunther R. Graetzer, *Secretary*

Aeroproducts Operations of General Motors Corporation's Allison Division

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Officers and Advisory Board members of the Hampton Roads Section are shown at the December 7 meeting. Seated *(left to right)* are: Emanuel Boxer, Chairman; Capt. Walter S. Diehl USN (Ret.), speaker; and Dr. H. J. E. Reid, Director of Langley Aeronautical Laboratory, NACA, Advisory Board. Standing are: William D. McCauley, Recording Secretary; M. H. H. Jackson, Advisory Board; J. Eggleston, Program Chairman; Richard Kuhn, Corresponding Secretary; J. D. Church, Vice-Chairman; William Alford, Advisory Board; Charles Zimmerman, Advisory Board; and Franklin Diederich, Treasurer.

was host to members of the Dayton Section on Thursday evening, December 9. Over 100 members signed up for this event; however, because of icy roads and snow, only 60 were able to attend.

Following dinner at the plant, slides on the features and applications of the Aeroproducts turbopropellers were shown along with a colored movie on turboprop power. R. R. LaMotte, Aeroproducts' Manager of Engineering, spoke on the reasons for the increased interest in turboprop power in both military and civil applications. The military turbopropeller development with its high horsepower in a small package, coupled with high efficiency and versatility, makes the reciprocating engine obsolete for many short-range or very long-range requirements where pure jet power is unfeasible. Shorter runways are made possible by the increased take-off thrust and the use of reverse pitch for landing.

Mr. LaMotte said that many of the new problems of control and safety, inherent in the high-r.p.m. turbopropellers, have been resolved so as to make this type of power plant safe and reliable. Some 10,000 hours of testing have been accomplished including over 1,000 flight hours on Aeroproducts turbopropellers. A new control approach is used involving a single power lever that coordinates propeller blade angle with the fuel control. In addition, a separate condition lever is used for air-starts, normal operations, and feather operations. Turbine r.p.m. limitations impose upon the propeller governor close control, particularly during transients involving large changes in power. This requires an acceleration-sensitive governor for matching blade angle closely with rapid power transients so as to prevent turbines from overspeeding and resultant overheating, overstress, and surge. In addition to feathering, reversing, synchronizing, and Beta and constant speed operation requirements, the following new safety features are required in turbopropellers to cover either propeller or engine failures and to prevent excessive drag with high inertia powered turbines: (1) mechanical low pitch stop (to prevent inadvertent reversals); (2) mechanical positive pitch lock (to lock pitch at existing blade angle in event of hydraulic power failure); and (3) separate mechanical negative torque signal (to feather the propeller automatically in event of engine failure).

Mr. LaMotte also mentioned that propellers under development for the military were expected to maintain reasonable high efficiencies into much higher speed regimes. These transonic and supersonic propellers have not been flown, but they will be physically available for flight early in 1955.

The meeting was followed by an interesting trip through the plant.

Hagerstown Section

A. Pickens, *Secretary-Treasurer*

The regular meeting of the Hagerstown Section was held in the Packet Room of the Terrace Restaurant on Wednesday, December 29.

The speaker, R. A. Darby, Fairchild's Chief Research and Development Engineer, was introduced by George White. Mr. Darby presented a paper entitled "A Discussion of Preliminary Design," dealing with the history and function of this important segment of the aircraft engineering department. Preliminary design work was divided into four main activities, which were discussed with special reference to the work of the Fairchild group. The subdivisions were: (1) design studies and preliminary engineering; (2) the preparation of proposals; (3) general research and development; and (4) operational analysis.

Mr. Darby concluded with the showing of slides to illustrate the nature of two projects recently undertaken by the Fairchild group. The first of these was the preliminary determination of an airplane design, using IBM computing equipment. The other problem was the experimental determination of boundary-layer profiles on the C-119 wing, using extensive flight-test instrumentation.

Following Mr. Darby's paper, refreshments were served by the Program Committee.

The meeting was concluded with the showing of a German film in which a large wind-tunnel model was used to demonstrate flutter theory.

Forty-three members and guests attended.

Hampton Roads Section

William D. McCauley
Recording Secretary

The Hampton Roads Section held its first dinner meeting of the 1954–1955 season on the evening of December 7. The dinner meeting was preceded by a social hour. Captain Walter S. Diehl, USN (Ret.), addressed the 99 members, their wives, and guests.

Captain Diehl was introduced by Dr. Henry J. E. Reid, Director of Langley Aeronautical Laboratory, NACA, who gave a brief résumé of Captain Diehl's colorful career in aeronautics.

A native of Jonesboro, Tenn., he received a B.S. degree from the University of Tennessee and did postgraduate work at M.I.T. From 1917 to 1951 he served with the Navy on engineering duty, and since his retirement he has been a consulting engineer. He has been associated with the NACA since 1919, has been a member of the Aerodynamics Subcommittee since 1924, and is the present Chairman of the Stability Subcommittee.

Speaking on "More Than Engineering," Captain Diehl said engineering as a profession has been with us for about 2 centuries. That makes it a mere infant in comparison with some of the ancient professions, such as medicine and law. However, engineering has been a lusty infant, showing great vitality and rapid growth. Is engineering growing up? Is it coming into a new status? The answer seems to be a strong "yes," he said.

Engineering always has been a demanding profession, but the demands are increasing. There are new responsibilities that cannot be evaded. The engineer, Captain Diehl said, must know more than engineering.

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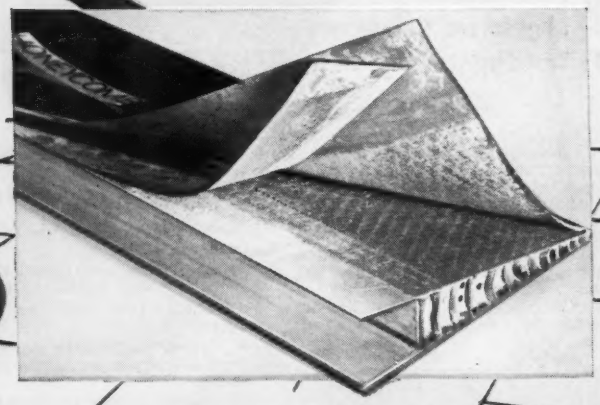

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For many years, he said, the engineering profession operated under some fancied and some real handicaps due to a lack of "social standing." Many, perhaps most, of the technical ancestors of the profession had little formal education and were regarded by society folk as coming from the wrong side of the tracks. This was, and it still could be, a matter for debate. There are two sides of the track. Which is the wrong side? Or better yet, is there a wrong side?

Although they lacked formal education, the first engineers were men of vision and energy. Their accomplishments eventually drove the scientists out of the ivory towers—one by one, as it were. Engineering education, as we know it, is a strictly modern phenomenon. It was not until World War II that the engineers became scientists and the scientists became engineers. Few people seem to realize the significance of the changes that have occurred. It is interesting to take a detached view of these things and note well what they mean.

The modern professional engineer builds on foundations laid by the military engineers of the past. For centuries the military engineers were an indispensable part of any army. They built bridges, roads, and fortifications—often under heavy fire. If necessary, they could fight. Make no mistake, the military engineers were hardy, courageous, and tough. We have great respect for these traits. The tradition of toughness persisted for a century or more after the original corps had been replaced by technically educated engineers.

"Some writers complain that this tradition has adversely affected the social standing of our profession," remarked Captain Diehl. "It has been my observation that the normal reaction of the average engineer is neutral or negative to this matter. First things have always come first in engineering."

The professional engineer has had still another hurdle to surmount, he pointed out. The industrial age was the age of steam. The inventive genius produced the idea and the working model, but it required a remarkable group of highly skilled mechanics to make these engines run and to find better ways of building the improved designs. These men knew and loved machinery. We owe them a great debt of gratitude. The inventive genius made the industrial age a possibility, but it was the operating engineers who made it a reality. We salute them.

The professional engineer of today has a splendid heritage from the days when engineering was for he-men only. He also has a real heritage from the operating engineers of the past. But a great technical gulf—a mountain range of technical data—separates that era

from the present. We are now in an age of technology. In the not too distant future, the professional engineers probably will find it desirable to follow the example set by physicians. The Doctor of Medicine must earn his title the hard way, but, once he becomes an M.D., there is no confusion with the medicine man, the chirurgeou, or bloodletting barber of a former day. It may become necessary for the professional engineer to adopt some other title that properly reflects the profound changes that are taking place. Will the professional engineer of the next generation be called a "Doctor of Applied Science"?

Regardless of what we as individuals want to do or can do, it is certain that we have now entered an era of intensive technical development. The future of this country, and perhaps of civilization itself, may indeed depend upon how well our engineers meet their increasing responsibilities. The engineer, Captain Diehl repeated, must know more than engineering.

Los Angeles Section

Joseph W. Wechsler, *Secretary*

The December dinner meeting of the Los Angeles Section was devoted to a reading of the Eighteenth Wright Brothers Lecture, "The Fatigue Life of Airplane Structures," by the author, Bo K. O. Lundberg, Director of the Aeronautical Research Institute of Sweden. The evening's program was made even more interesting for the 350 IAS members and guests who attended when prepared comments were delivered by Jerome F. McBrearty and Richard L. Schleicher, Chief Structures Engineers at Lockheed Aircraft Corporation and North American Aviation, respectively. Since both the lecture and comments will be published in full in the JOURNAL OF THE AERONAUTICAL SCIENCES, they will not be summarized here.

On the day preceding the meeting, a reception was held in Mr. Lundberg's honor which enabled him to meet many of the people connected with the aircraft industry in the Southern California area. At the social hour immediately preceding the meeting, Mr. Lundberg was once more able to chat with the local engineers and executives. As a result, the members of the Section were able to become better acquainted with the speaker than if they merely saw him on the rostrum.

Special guests for the evening were Walter G. Danielson, Consul of Sweden at Los Angeles; Eric Broman, Manager, Propulsion Section, Guided Missiles Department, Swedish Aircraft Board; and Dr. Richard Shaw, Chief, Airworthiness Section, Department of Civil

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Aviation, Australia. Warren Dickinson, Section Chairman, presided at the meeting and introduced the speaker.

Richard Boyles, Jr.
Member, Specialist Meetings Committee

▶ At a specialist meeting held on December 14, J. F. Johnston, Group Engineer, Dynamics Group, Lockheed Aircraft Corporation, described "Transonic Flutter Tests with Rocket-Propelled Models." Eighty members and guests were present.

After outlining the essentials of this well-publicized research project—the dynamically similar wings and high-speed cameras mounted on 5-in. rockets—Mr. Johnston described the development of special equipment used in the tests and the methods used in recording and analyzing the data. He also compared the test results to analytical solutions for the same transonic problems.

After showing some of the test films, the meeting was concluded by a lively discussion from the floor and inspection of some of the special test equipment mentioned above.

Niagara Frontier Section

Clifford L. Muzzey, *Secretary*

The November 10 meeting of the Niagara Frontier Section of the IAS was held at the Crosby-Braunschidel Veterans' Club. The purpose was to discuss several items of business that would interest the membership. Following reports by the Secretary and Treasurer, Vice-Chairman Bob Goldin discussed the work of the Program Committee and the meetings they have planned for the 1954–1955 season.

Dick Koegler then gave an informative discussion of the Technical Societies Council of Buffalo, tracing its beginning from 1946 and showing its relation to the individual engineer, the local engineering societies, and the community. Dick, a Past-President of the Technical Societies Council, is presently a Council delegate from the IAS.

Two motion pictures were shown after the close of the business transactions. The movies, released by Bell Aircraft Corporation, were *The Farmer in the Bell*, depicting many agricultural uses of the helicopter, and *Flight Report, X-1A*, showing preparation and flight of Bell's latest high-speed research airplane at Edwards AFB.

Seattle Section

Louis Schmidt, *Secretary*

The Seattle Section met November 17 at the Benjamin Franklin Hotel. The large turnout was an index of local interest in the evening's topic, "A Report on the 707."

A. M. Johnston, Chief of Flight Test at Boeing Airplane Company, acted as Toastmaster.

The first speaker was D. W. Finlay, Project Engineer, Boeing Airplane Company. His discussion of a few of the structural design considerations evoked much interest, for this was the first time most of us had heard the behind-the-scenes reasons for some of the structural details. Mr. Finlay said that consistently good operation during flight tests has tended to prove the soundness of the basic design philosophy.

R. J. White, Project Aerodynamicist, presented the background of aerodynamic considerations that led up to the final prototype configuration. A limited amount of flight-test results was presented to demonstrate the excellent agreement with predictions. It was pointed out that successful operation of the air frame in these early tests would not have been possible without the help of the proved J-57 power plant. His concluding remarks on aerodynamic concepts gave an insight into design that disproved the "crystal ball" approach often associated with aerodynamicists.

G. W. Taylor, Manager of Domestic Sales, discussed the domestic and international sales potentials of a jet transport type of airplane. He said that in addition to obvious military applications, its basic economic soundness makes this type of vehicle attractive to the commercial operator. Statistics were presented to verify these statements.

The speakers showed motion pictures and slides, including glimpses of the Boeing 707 in different stages of flight test.

Twin Cities Section

Thomas W. Chase, *Secretary*

Section officers were elected at the December 16 meeting. The result of the election is as follows: Chairman, Bob Hoel; Vice-Chairman, Dr. Rudolf Herman; Treasurer, Robert Holdahl; and Secretaries, Herbert Johnson and Thomas Chase.

The Advisory Board is composed of John Akerman, Don Benson, Al Cronk, Orin B. Johnston, Dave Mellen, and L. L. Schroeder.

Student Branches

Academy of Aeronautics

John A. Hope
Corresponding Secretary

The first meeting during December was held on the first day of the month. Chairman Robert Zincone suggested that our group make a field trip to Grumman Aircraft Engineering Corporation. A motion to this effect was passed, and the trip was scheduled for December 8. The meeting was brought to a close with the showing of a film entitled "British Aircraft Review." There were 38 students present.

▶ On December 8, the field trip to Grumman was made by 40 members of our Branch. The tour included the Assembly Department where we witnessed the production methods employed by a plant of this type. Because of security regulations, we were unable to see their Engineering Department. The tour closed with a luncheon served in the company cafeteria.

▶ The final meeting of 1954 was held on December 15 and was attended by 21 members. It was moved that a field trip to The Glenn L. Martin Company be made in January as the last outing of the term.

The Aeronautical University

John R. Lundberg, *Secretary*

The Aeronautical University held its monthly meeting of the Student Branch of the IAS November 24. Five films were shown at this meeting.

Plans were made to meet with the student branches of the University of Illinois (Navy Pier) and the Illinois Institute of Technology for a planning session regarding the student meeting of the Chicago Section of IAS in March. Suggestions for the title of the March meeting were taken by the Chairman. Some of these were "Experimental Aircraft," "Roadable Aircraft," "Gliders," and "Kit Aircraft."

▶ Several of our members attended the Chicago Section meeting on December 2. They were impressed by the speaker, Dr. Walter Dornberger, and his predictions on space travel.

California State Polytechnic College

Robert Evans, *Reporter*

Fifty Student Members and faculty attended the November 18 meeting of the California State Polytechnic College Student Branch.

After the business meeting, Chairman Jack Gresham introduced George A. Starbird, President of the Meletron Corporation, of Los Angeles, who spoke on "The Farnborough Show." Mr. Starbird exhibited a motion picture he had made in England in 1953, which showed 15 of the newest British airplanes being put through their paces in flight. He then elaborated on his trips to England in 1953 and 1954, describing

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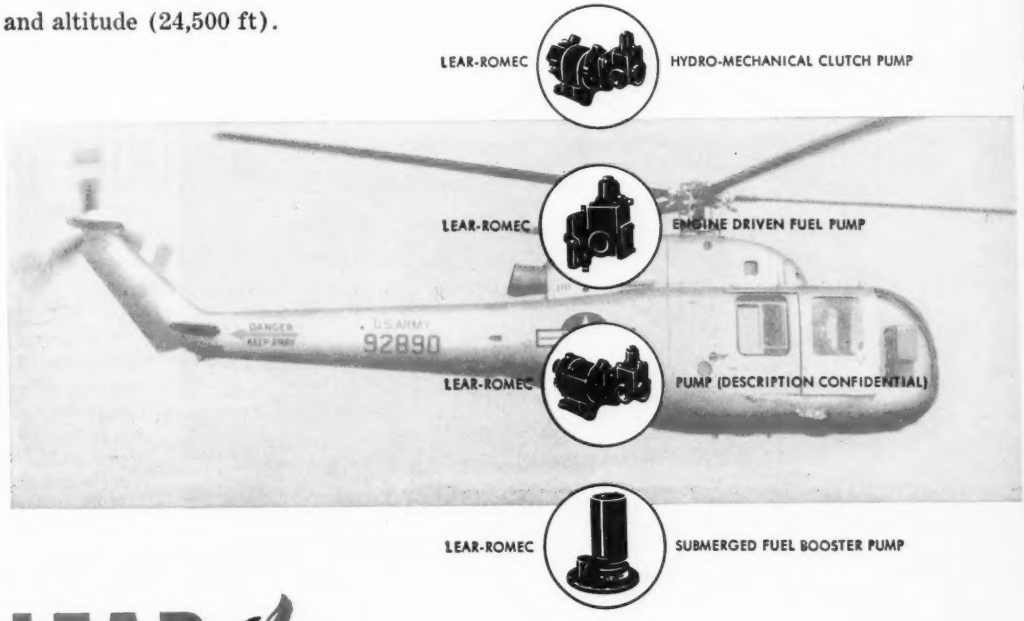

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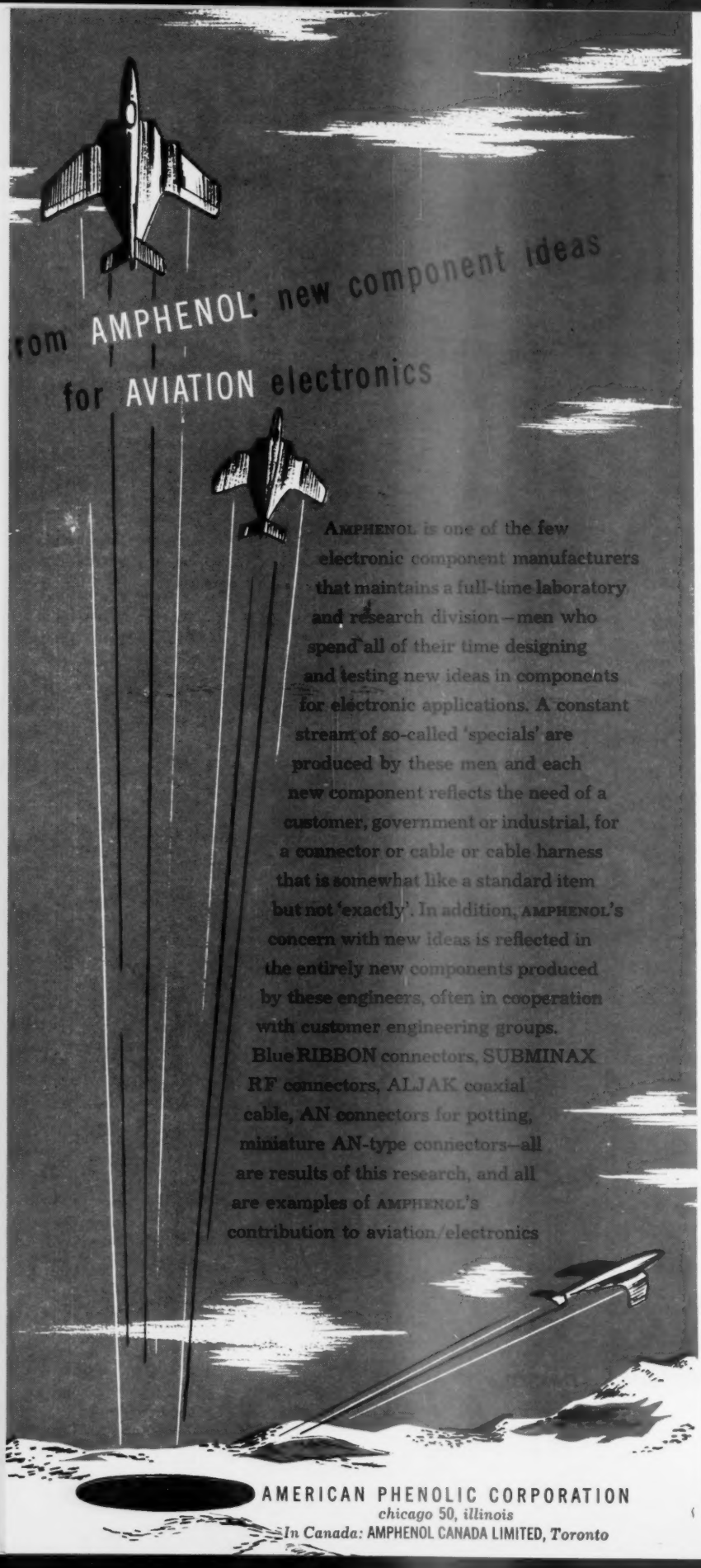
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the overall scene of the 6-day event at Farnborough and the indoor static displays of the engine and air-frame manufacturers. He also spoke about British aircraft production, production techniques, and design methods.

Mr. Starbird showed another film, *The Meletron Story*, which pointed out how and where vacuum and pressure switches can be used in aircraft and described different types. This film covered production methods and testing at the Meletron plant.

Mr. Starbird concluded his talk with a brief discussion of vibration and the serious problem it presents to the aircraft industry.

The Catholic University of America

Nicholas R. Gallipoli, *Secretary*

The Catholic University of America Student Branch of the IAS held its first meeting of the year November 22. Robert E. Kastner, last year's Secretary, called the meeting to order. Welcoming newcomers, he outlined the functions of the IAS and told what they could expect from the Institute.

New officers for 1954–1955, elected at this meeting, are: Robert E. Kastner, Chairman; Nicholas R. Gallipoli, Secretary; and Zeigler O. White, Treasurer.

Chairman Kastner described the program he had in mind for the coming year. He suggested inviting speakers who would talk on various phases of aeronautical engineering and on the aeronautical engineer's place in the business world. He said movies would be obtained to present technical phases of aeronautical engineering.

Peter R. Bogan was appointed to procure speakers for future meetings.

Iowa State College

J. L. Midgorden, *Secretary*

The meeting of December 8 of the IAS Student Branch at Iowa State College was called to order by Chairman Philip Smith. The minutes of the November 10 meeting were read and approved. There were no committee reports and no old business.

Student Members Walter Dunn and William Kieffe each presented a report. Mr. Dunn's was entitled "The Importance of Maintenance." In it, he cited many examples of careless maintenance and disastrous results that often follow.

Mr. Kieffe's report was on the much debated subject of the British Comet I and the Comet inquiry. The speaker discussed the various procedures that the British have been using in determining the failure of the Comets.

Dr. Glenn Murphy announced that Capt. J. L. Pritchard, former Secretary and presently Council Member of the Royal Aeronautical Society, will be on

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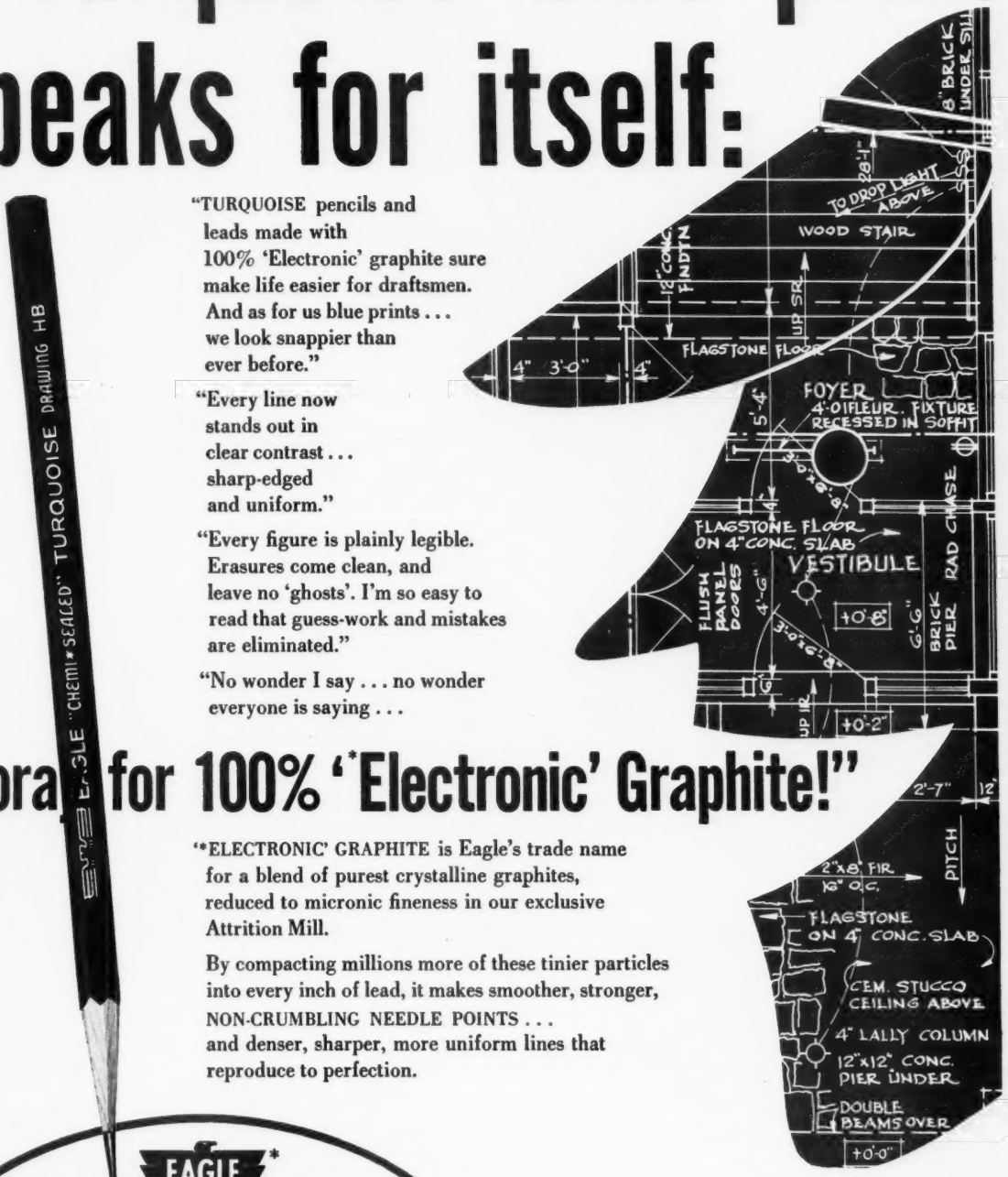

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campus on February 28 and 29 for a series of talks.

The meeting was adjourned, and refreshments were served.

Mississippi State College

Charles J. Dixon
Corresponding Secretary

On November 18, a meeting was held at which Joseph J. Cornish, of Mississippi State's Aeronautical Physics Department, spoke on "The Realm of Flight." This was an interesting talk that covered the progress of flight from insects and seeds up to present and future flights by man. When the speech was concluded, everyone adjourned to a party held by our Student Branch.

▶ On December 2, another meeting was held. After a short business session, Glenn Bryant spoke on "Wide Speed Range Aircraft." Mr. Bryant is a member of the school's Aeronautical Physics Department. His talk gave some of the ideas and proceedings of increasing the speed range of today's aircraft.

North Dakota Agricultural College

James W. Giese
Secretary-Treasurer

Officers elected during the fall semester are as follows: Chairman, Ronald Martin; Vice-Chairman, Paul Hoekstra; Secretary-Treasurer, James W. Giese; and Student Council Representative, Gary Hiedilbaugh. The Faculty Adviser is Prof. Frederick W. Stuve.

Meetings were held during the 1954 fall semester on October 13, November 16, and December 14.

The Pennsylvania State University

E. Allen Weber
Secretary-Treasurer

The Pennsylvania State University Student Branch of the IAS met December 8 at the Penn State campus with 65 students attending. Chairman Ralph Straley presided.

The IAS career guidance booklets were distributed and various topics contained in them were discussed.

Two films obtained from IAS were shown. One film, *Wright Builds*, described manufacturing processes involved in building an airplane engine. Although there was not much discussion of technical difficulties, actual steps in the construction such as casting, heat-treating, and assembly were shown in detail. The other film, *Operation Airborne*, was an excellent description of the C-124 Globemaster and its tremendous load-carrying capacity.

Polytechnic Institute of Brooklyn

Murray Rosenberg, *Secretary*

The third and last meeting of a series of talks on space travel, held jointly with the Math Club, Physics Society, and IAS Branch at Brooklyn Polytechnic Institute, was attended by 65 persons on December 14. Chairman Louis Divone presided. Oscar E. Holt, Manager, Electro-Mechanical Engineering Department, W. L. Maxson Corporation, was our guest speaker.

Mr. Holt, who is a member of the American Rocket Society and an authority on space travel, began his discussion with a brief outline of man's attempts to leave the surface of the earth, from the primitive leap to the modern rocket research aircraft.

Continuing, Mr. Holt specified the two foremost factors in the design of a space rocket: the accelerations experienced by the structure and the aerodynamic drag that causes skin heating. The higher the acceleration of the ship, the more efficient it is. Or, the smaller the percentage of the total acceleration used to overcome gravity, the more efficient the ship. Although high accelerations are efficient, the acceleration that a human being can take is limited. Since a high velocity would be reached before the rocket is out of the atmosphere, aerodynamic heating poses a serious problem. The speaker then presented some proposed solutions to these problems. Among them he included the three-stage ship for smaller accelerations; firing rockets from artificial or real satellites; and, as a passing remark, he mentioned the science-fictionist's favorite, the anti-gravity machine.

On the subject of propulsion systems, Mr. Holt mentioned the atomic power plant, which uses the heat of the pile to vaporize some of the liquid to provide the propulsive force. He said that this form of system is not efficient. Mr. Holt also mentioned recent calculations for the use of high-intensity light rays for propulsion in space. The calculations indicate that the intensity must be ten times that of the sun.

The talk was concluded with an appraisal of the problems of guidance and navigation which will be encountered in space. Mr. Holt, whose work is in the electromechanical devices field, said that major advances in the field of sensing and navigational tracking devices must be made, if these problems are to be solved.

Ralph McGuire, Assistant to the Vice-President in charge of Engineering, Eastern Air Lines, was guest speaker at the December 21 meeting of this Branch. He spoke on "Commercial Jet Transports" and gave background material on recent developments in the field, discussing some of the problems being studied by air lines and manufacturers.

Speaking from the commercial air lines' point of view, Mr. McGuire gave the following requirements for a jet air liner: it must be safe, fast, and economical; it should have reasonably quiet engines and be able to operate from existing runways; it must operate at a profit.

On the topic of safety, the speaker developed such aspects as high-altitude explosive decompression and the fire hazard from poor engine and fuel placement. He also touched on structural battering at sonic speed.

Mr. McGuire pointed out the close relation between economy and profit, emphasizing that economy covers a much greater field. Economy of fuel consumption, for example, is important, since fuel stowage is usually a major factor in design, affecting the size and structure of nearly every part of the air frame. The ducted fan engine, a recent advance in engine design, will greatly minimize the problem of fuel consumption. The speaker said that commensurate with lower fuel consumption, this engine has a lower noise level, a desirable attribute.

Mr. McGuire illustrated his talk with slides, including some on shock-wave production, and some graphs on time vs. development.

Purdue University

David L. Beaver, *Secretary*

The Purdue Student Branch of the IAS held its regular December meeting on the fourteenth, with its first out-of-town speaker. The guest speaker was W. H. Clausen, Chief of Engineering Services, Aeronautical Division, Minneapolis-Honeywell Regulator Company.

During Mr. Clausen's visit, the Student Members acted as hosts, introducing our guest to the faculty members, showing him the facilities of the Purdue Aero School, and entertaining him at dinner before the evening meeting.

The evening program centered about Mr. Clausen's talk on "Problems of Developing and Producing Quality Aircraft Controls" which was greatly enjoyed by the Student Members and five faculty guests. Slides were also shown, giving the members an idea of the products that have become realities through intensive research and development. In addition, a greater respect for the controls and equipment engineers was developed through this talk—just through the realization of the problems these engineers have faced and the ways they have arrived at satisfactory solutions.

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Stanford University

Richard Knox, *Chairman*

The IAS Student Branch at Stanford University has been reactivated. The faculty sponsor is Prof. S. J. Kline. Thirty members had been recruited up to Thanksgiving, and eventually the membership should exceed 50.

Two meetings have been held jointly with the local ASME Student Branch. The first, held at Professor Kline's house, served to get students and faculty better acquainted. At the second meeting, engineers from the Pontiac Division of General Motors presented a discussion of spark ignition engine design.

USAF Institute of Technology

Lt. Joseph Joyce, *Secretary*

On November 18, John B. Trenholm and N. Erkenoff, of the Wright Air Development Center Fighter Branch, delivered a classified lecture on Project X-13, currently being developed by WADC. Slides and a movie were used to illustrate the talk. The program was attended by the IAS Student Branch members, IAS members, and engineers from the Wright Air Development Center.

University of Colorado

Jack W. Kenney, *Secretary*

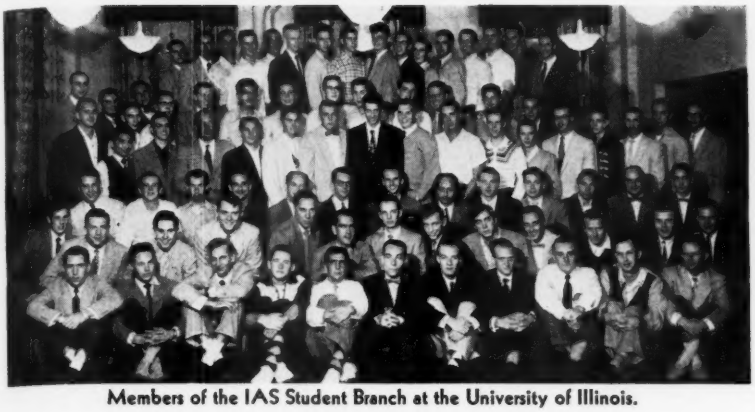
At the University of Colorado Branch meeting October 20, plans were discussed for establishing the Jim Polosky Award for the top graduating aeronautical engineer. Mr. Polosky was Chairman of the IAS Branch at University of Colorado for the year 1953–1954. He was killed recently while flying for the Navy. The plaque is to be sustained by this Branch.

Professor F. P. Durham of the Aeronautical Engineering Department spoke on the advantages of entering the student paper competition sponsored by the Texas Section of IAS. He told how to enter, types of papers to be entered, how the contest is sponsored, and highlights of the contest.

Chairman Harvey C. Gerhard presided. Fifty-one members were present.

▸ Chairman Gerhard presided at the U. of C. Branch meeting November 11. The Polosky Award and student paper competition were discussed.

W. S. Knowlton, General Electric's Field Plant Representative for the Rocky Mountain Region, gave a talk on gas turbines, basing it on G-E's J-47 and J-57 engines. Fuel consumption and relative air velocities were discussed. He explained the importance of each factor and the goals being sought. Emphasis was placed on jet-engine augmentation. External tailpipe aug-



Members of the IAS Student Branch at the University of Illinois.

mentation and internal augmentation were explained. Internal augmentation includes preturbine and water-alcohol injection. The advantages and disadvantages of these types of augmentation were discussed.

The talk then turned to the requirements for fighter and bomber airplanes. The speaker also reviewed commercial and helicopter needs for jet engines and showed slides of the J-47 turbojet.

A G-E film describing electronic controls for the J-47 engine with afterburner was shown. It explained how the complex fuel-control problems are controlled and what precautions a pilot must take in starting and operating the jet engine. The complete instrument check that the pilot must keep was shown and discussed. D. A. Pullen, G-E Sales Representative for this region, assisted Mr. Knowlton in the presentation.

University of Michigan

Roger J. Nyenhuis, *Secretary*

Amos Wood, Service Manager of Boeing Airplane Company, spoke at the October meeting of the University of Michigan Student Branch. The duties of the Service Department are diverse, he said, explaining the usual problems that arise after the airplane has left the factory. The Service Department makes technical orders concerning the aircraft, trains maintenance personnel, designs ground support equipment, and, finally, decides what has gone wrong, and why, when difficulties are encountered with the aircraft. Mr. Wood emphasized the importance of having each system as reliable and trouble-free as possible.

Two films produced by the Boeing Engineering Photo Unit were shown: *Flutter of Elastic Models* and *The GAPA Story*.

▶ The meeting of December 8 was called to order by Chairman Bill Sproull.

After a business meeting, John S. Squires, Director of Customer Engineering of Continental Motors Corporation, spoke on "Small Gas Turbines." The development of the small gas turbine, he said, has not proceeded so rapidly as development of the larger gas turbines because there is less demand for a small gas turbine. The gas turbine being produced by Continental Motors was initiated by Turbomeca in France and licensed to Continental Motors for production in the United States.

Some of the models being introduced are the turbojet, turboprop, ducted fan, and free turbine. Various applications of these models have been made in light aircraft, jet trainers, helicopters, large jet aircraft engine starters, and air compressors. Slides were shown of the performance curves for the different models of gas turbines and cutaway views of the various models. Mention was made of the difficulties encountered in scaling an engine from French to American dimensions. Other changes were necessary because an American engine is required to have more safety devices than a French engine. Mr. Squires answered questions at the end of his talk.

University of Minnesota

Tom Ernst, *Secretary*

Chairman Dave Boslough opened the meeting of October 18 at 7:30 p.m. After a word of welcome to those attending, he introduced the IAS Student Branch officers for the coming year. These officers are: Vice-Chairman, Dale Holasek; Secretary, Tom Ernst; Treasurer, Dick Rozycki; and Publicity Chairman, Marvin Luger. A business meeting followed.

The speaker of the evening was Prof. John D. Akerman, Head of the Department of Aeronautical Engineering at the University. Professor Akerman first listed the advantages of membership in the Institute and then gave a summary of the history of the department he heads.

▶ The meeting of November 30 was opened by Chairman Boslough at 7:30 p.m. At the conclusion of the business portion of the meeting, Ben Ciscil, Project Engineer with Minneapolis-Honeywell Regulator Company, was introduced as the speaker of the evening.

Mr. Ciscil gave an interesting talk, illustrated with slides, on his company's E-10 Autopilot. He outlined the development of the autopilot, showed a typical control system with an automatic pilot, and explained some of the operations of the E-10 Autopilot. He stated that, although the E-10 Autopilot is capable of performing more operations than previous autopilots, it is lighter. A question-and-answer period followed his talk, after which the meeting was adjourned.

University of Notre Dame

Leon E. Ring, *Secretary*

At the regular Branch meeting on November 22, Vice-Chairman Robert Gervais reported the condition of Chairman Martin Kenehan, who was stricken with polio, as greatly improved. Mr. Gervais will serve as presiding officer for the remaining term.

After the business meeting, Frank N. M. Brown, Head of the Aeronautical Engineering Department, gave a talk on "The Position of an Aeronautical Engineer."

University of Southern California

D. A. Russell, *Secretary*

At the meeting of December 1, a short color film entitled *NACA Pilotless Aircraft Research* was shown. The film describes the firing of various rockets and the primary effects of aspect ratio and sweepback on a rocket's drag.

The second meeting was on December 15. It was a joint meeting with the local branch of ASME to hear an excellent lecture on "Stability and Control in the Modern Aircraft." It was ably delivered by Roy Tonhof, Test Pilot for Northrop Aircraft, Inc.

▶ On December 22, some members participated in an all-day tour of the U.S. Naval Ordnance Test Station's underwater ordnance facilities in the Pasadena, Calif., area. This tour, of a most complete nature, dealt with the development of air-sea torpedoes and included a demonstration of the $2,000,000 variable-angle torpedo launcher at the Morris Dam Range.

University of Tulsa

Wyman Barnes, *Secretary-Treasurer*

On November 18, the second meeting of this school year was called to order at 7:30 p.m. by Chairman Don Boyd. The attendance was 22.

Lloyd Jackson, Assistant Strength Group Engineer for Douglas Aircraft Company's Tulsa, Okla., Division, gave

a talk on "Aircraft Engineering." He listed the various design and technical groups at the plant, giving a résumé of each. Mr. Jackson explained in considerable detail the ways in which the technical groups deal with stability and control, stress analysis, testing, and weight control of an airplane. He also related the duties and importance of the Liaison Department.

Vice-Chairman Don Funk told about a meeting that he, Chairman Boyd, and Prof. J. C. Klotz, our Faculty Adviser, attended at the Oklahoma A&M of the IAS and SAE student branches at Stillwater, Okla. This meeting was concerned with the development of cars in the future. These cars, it was said, will have more horsepower and longer, lower design. The top horsepower was predicted to be around 300 hp. by 1960. In the years to come, there will be a trend toward a lower weight-to-horsepower ratio, and cars will be heavier in front because of added horsepower. It was also predicted that turbine cars will not be on the market until about 1965.

A film, *World War II Planes in Action*, was then shown. This picture depicted actual combat between American and German planes and showed how our planes destroyed the German transportation system.

Plans for visiting two aircraft companies over the Thanksgiving holidays were cancelled, because the plants in question would not be in operation at that time. The suggestion was advanced that a field trip be made at Easter.

The meeting was adjourned at 10:00 p.m.

University of Washington

Bud D. Nelson, *Secretary*

The evening meeting of December 1, featured O. C. Weller of the Structural Development Department, Boeing Airplane Company. Mr. Weller presented a very enlightening talk and demonstration on "Aircraft Materials for the Future."

The main discussion considered two topics: foam structure and honeycomb structure. Mr. Weller demonstrated the chemical formulation of several different types of fast foam structure and passed them around for visual inspection by those in attendance.

Foam in many weights and strengths can be applied to many areas of use. Advantages of the foam as filler for unsupported skin are its light weight and prevention of skin oil-canning, thus contributing to the stability of the skin at high speeds. Also foam filler for small assemblies shows a large cost saving over riveted assemblies.

Mr. Weller also described the advantages and disadvantages of honeycomb structure in future primary structure. The manufacturing process, at present, using a hydrocarbon bonding agent, limits the honeycomb material to aluminum foil. The bonding agent also limits the upper temperature range. Stainless steel honeycomb has been fabricated by brazing.

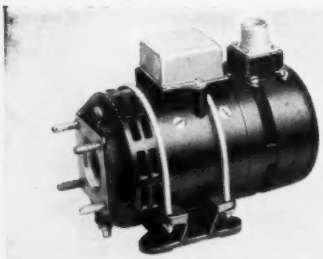
Mr. Weller pointed out that aluminum is the only honeycomb presently manufactured in various strengths.

West Virginia University

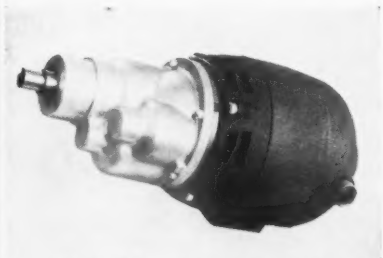
Donald R. Peters
Corresponding Secretary

Chairman Benjamin D. Grove addressed the November 3 meeting of this Branch. He then introduced the Honorary Chairman, Prof. Leon Z. Seltzer, who presented a summary of recent research in aeronautical engineering.

The topics covered by Mr. Seltzer in his most entertaining, as well as educational, summary were: (1) structures—materials, harmonic analysis, oscillating wings, multiweb wings, and aerodynamic heating; (2) aerodynamics—aerodynamic efficiency, boundary-layer control, and the aerodynamic properties of helicopters, and (3) propulsion—systems and applications, fuels, and combustion.



Aircraft hydraulic pump motor. Maximum output with minimum weight.



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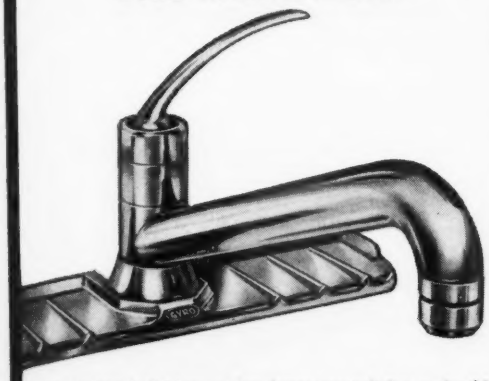
Waldes Truarc ring reduces valve body from 1 5/16" to 1 1/16", eliminates chrome plating

GYRO MIXING FAUCET



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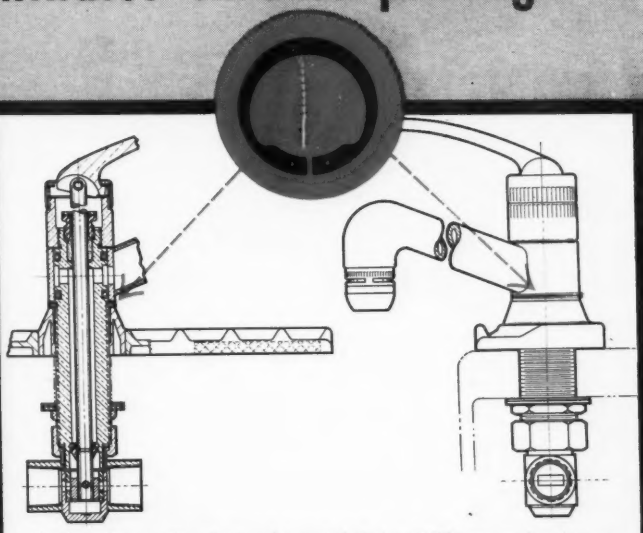

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Dr. Jack W. Carter of the Structures Department of The Glenn L. Martin Company was a guest at the meeting.

At a later date, the Branch attended a showing of two movies, *The Fleet that Came to Stay* and *Building of the B-26*.

▶ Chairman Grove addressed the December 8 meeting of this Branch. In discussion of campus business, Mr. Grove reported that the name of the annual dance sponsored by the engineering societies was changed from Engineers' Ball to Midwinter Prom.

An announcement was made that the election of officers for the coming semester would be held during the Branch meeting on January 5, 1955.

Two movies, *PBY Record Holders* and *Construction of the Cub*, were shown.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Gray, Edward Z., B.S.C.E., Chief—Stress, Boeing Airplane Co. (Seattle).

Martin, George C., B.S. in Ae.E., Chief Engr., Boeing Airplane Co. (Seattle).

Von Handel, Paul, D.Sc., Sr. Electronic Scientist & Scientific Adviser, Holloman Air Development Center.

Transferred to Associate Fellow Grade

Beal, Ralph R., Jr., A.B., Supvr., Test Proj. Engrg., Wind Tunnel Sect., Jet Propulsion Lab., California Institute of Technology.

Church, James D., B.S.Ae.E., Aero. Research Scientist, Stability & Control Branch, Pilotless Aircraft Research Div., NACA, Langley AFB.

Davis, Frank W., B.S.M.E., Chief Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

Friedrich, Hans R., Ph.D., Dynamics Group Engr., Convair-San Diego Div. of General Dynamics Corp.; Lecturer of Engrg., UCLA.

Fuller, Richard G., B.Sc.M.E., Aerodynamics Group Engr., Lockheed Aircraft Corp.

Gustafson, Robert L., B.S., Chief—Aerodynamics, Grumman Aircraft Engineering Corp.

Immenschuh, William T., Chief, Test Operations, Ryan Aeronautical Co.

Maske, Edmund B., Jr., M.S.Ae.E., Chief—Aerodynamics, Convair-Ft. Worth Div. of General Dynamics Corp.

Smith, Apollo M. O., M.S. in Ae.E., Supvr., Design Research, Douglas Aircraft Co., Inc. (El Segundo); Lecturer, UCLA.

Tripp, Ralph H., Ph.D. Applied Math., Chief, Instrumentation Dept., Grumman Aircraft Engineering Corp.

Elected to MEMBER Grade

Antoniak, Charles, M.S. in Ae.E., Special Corp. Rep. & Consulting Engr., Solar Aircraft Co.

Bloom, Rex G., Mechanical & Aeronautical Engr., Radioplane Co.

Blount, Gilbert M., M.S., Flight Test Operations Mgr., Boeing Airplane Co. (Seattle).

Breitwieser, Charles J., M.S., V-P—Engrg.; Div. General Mgr., Research & Development Div., Lear, Inc.

Calvert, C. E., B.S., Aeronautical Research, Design & Development Engr., Strategic Air Command.

Cantwell, Raymond A., B.S.Ae.E., Sales Engr., Lockheed Aircraft Corp. (Marietta).

Carter, John L., Jr., B.S. in M.E., Asst. Proj. Engr., Propeller Div., Curtiss-Wright Corp.

Day, Barton E., B.S., Capt., USN; Asst. BuAer General Rep., BAGR-CD, Wright-Patterson AFB.

Dunning, Robert W., B.S., Physics, Aero. Research Scientist, NACA, Langley AFB.

Fouch, George E., M.B.A., General Mgr., Jet Engine Dept., AGTD, General Electric Co. (Cincinnati).

Gran, Warren M., B.S. in M.E., Sr. Engr., Cook Research Labs.

Hansard, John B., B.Ae.E., Sr. Structures Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

Hemphill, George W., Aero. Design Engr., Aircraft Div., Fairchild Engine & Airplane Corp.

Hodges, Beverly W., B.S.C.E., Chief, Structural Staff, Boeing Airplane Co. (Wichita).

Johnson, Elmer G., B.M.E., Asst. Chief, Fluid Dynamics Research Branch, USAF, WADC, Aero. Research Lab. (WCRRD), Wright-Patterson AFB.

Johnson, Herbert C., B.S. in M.E., Proj. Engr., Research, Inc.

Maekawa, T., Dr. of Sc., Prof., Faculty of Sciences, Hiroshima Univ.

May, Edwin T., Acoustical Engr., Industrial Sound Control.

McIntosh, William A., M.S.M.E., Thermodynamics Engr., Convair Div. of General Dynamics Corp.

Mengel, William E., M.S. Mechanics, Asst. Chief Test Engr., McDonnell Aircraft Corp.

Meyer, Richard E., Dr.Sc., Techn. E.T.H., Sr. Lecturer in Aerodynamics, Univ. of Sydney.

Naiman, J. M., B.S. in M.E. & E.E., Private Research in Fluid Mechanics & Consulting Engrg., Self-Employed.

Ostroff, H. H., B.S.A.E., Chief Propulsion Engr., Helicopter Div., McDonnell Aircraft Corp.

Paige, Hilliard W., B.S.M.E., Mgr., J-73 Proj. Sect., AGTD, Jet Engine Dept., General Electric Co. (Cincinnati).

Pusack, George W., M.S.M.E., Staff Engr., Gasoline & Fuel Oil Dept., Socony-Vacuum Oil Co., Inc.

Sano, Julian H., B.M.E., V-P, Chief Engr., Colvin Labs.

Schmidt, R. R., Head, Structural Group, Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Siewertsen, H. A., B.A., Mech. Engr., Hughes Aircraft Co.

Smith, Claude W., Lt. Col., USAF; Commander, 1700th Test Sq. (Turbo Prop), MATS, USAF (Kelly AFB).

Taylor, Robert I., B.Sc., Sect. Leader, Wind Tunnels, Vickers Armstrong Ltd.

Van Der Walt, N. T., B.Sc. (Eng.), Tech. Engr., Hedley S. Crabtree & Co., Ltd. (Engrg. Consultants).

Watson, Alexander M., B.Sc., Field Installation Engr., United Aircraft Service Corp.

Wehrli, Robert L., M.S. in Physics, Dir.—Research & Development, Robertshaw-Fulton Controls Co.

Whipple, G. Graham, Tech. Representative, Aerojet-General Corporation.

Whitener, Philip C., B.S. in M.E. (Aero.), Group Engr., Boeing Airplane Co.

Wilkins, Richard S., B.S.E. (Ae.E.), Application Planning Engr., AGTD, General Electric Co. (Cincinnati).

Transferred to MEMBER Grade

Allan, Donald G., M.Sc. in Ae.E., Lecturer, Dept. of Aero. Engrg., Faculty of Applied Science & Engrg., Univ. of Toronto.

Athen, Adolph J., M.S.M.E., Group Leader, Research & Development Engrg., Sperry Gyroscope Co., Inc.

Bell, Robert Edward, B.S.M.E., Field Engr., Pacific Scientific Co.

Boyer, Luther J., M.S. in Ae.E., Supvr., Flight Test Engrg., Chance Vought Aircraft, Inc. (Dallas).

Brooks, Doyle T., B.S. in Ae.E., Chief of Structures, Temco Aircraft Corp.

Bull, Gerald V., Ph.D., Head, Aerodynamics Sect., Canadian Armament Research & Development Establishment.

Chou, Pei Chi, Dr. of Engrg. Sc., Asst. Prof. of Aero. Engrg., Drexel Institute of Technology.

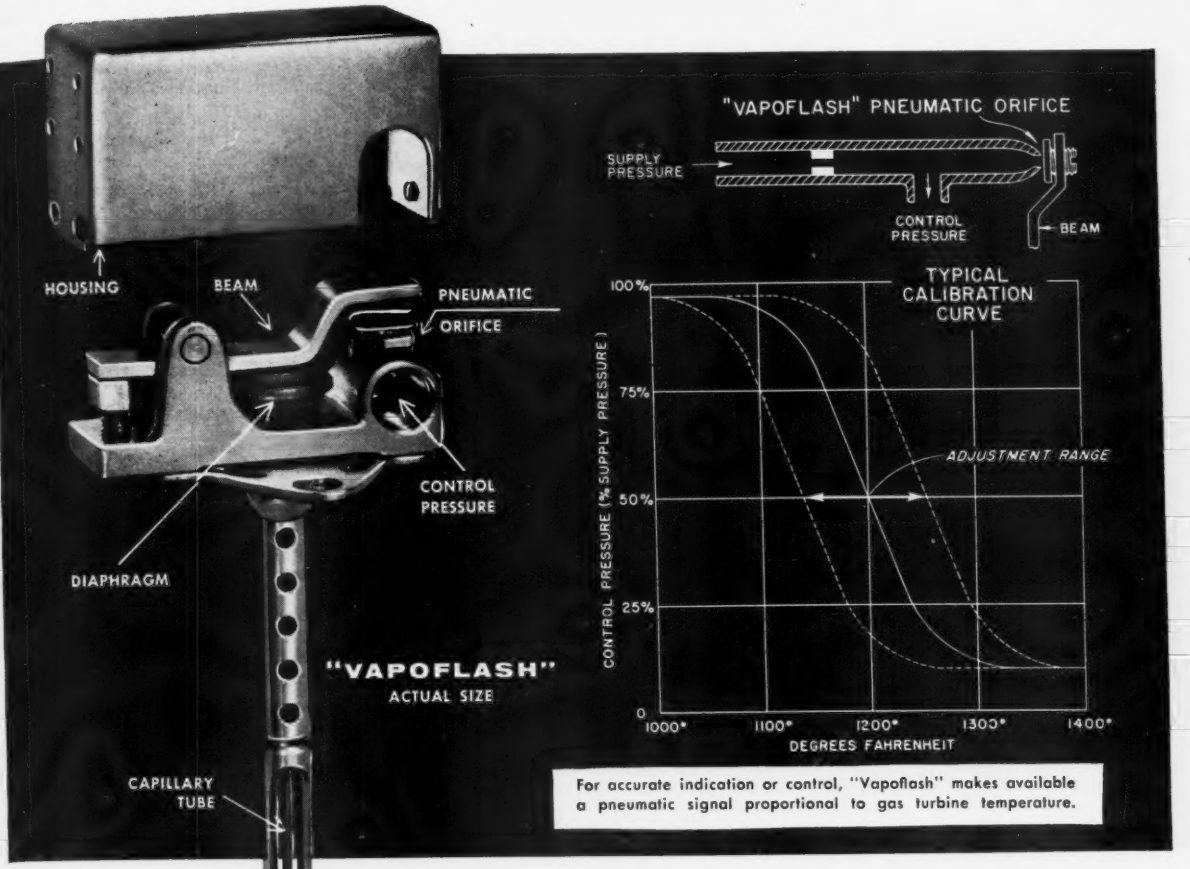
de Lancey, Lawrence M., B.S.M.E. (Aero.), Head, The Experimental Research Sect., Aerodynamics Branch, U.S.-N.O.T.S. (Inyokern).

Fossier, Mike, A.E., Staff Engr., Raytheon Mfg. Co.

Foy, Egan D., Asst. Proj. Engr., assigned to the Cutlass Program, Chance Vought Aircraft, Inc. (Dallas).

Frost, Richard C., M.S. in Ae.E., Sr. Aerodynamics Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

Goslee, John W., B.S.Ae.E., Service Engr., Aircraft Fuel Metering Technical



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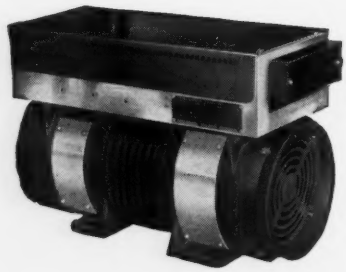

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12126	27.5	2	26	3	10	2.3	35000	N1020-SK
MG-93	27.5	12	115/200	1	100	10	65000	E-5134
				3	100			
MG-54	27.5	22	115/200	1	250	17	65000	E-5109
				3	250			
12142	27.5	22	115	1	250	13	35000	E-1617
				3	250			
12146-1	27.5	22	115	1	250	13	35000	53B6239
12146-2	27.5	22	115	3	250	13	35000	AN3532-2
MG-60	27.5	22	115	1	250	17	50000	53B6239
MG-62	27.5	22	115	3	250	17	50000	AN3532-2
32E01	27.5	35	115	1	500	26	50000	AN3533-1
				3	500			
32E00	27.5	37.5	115	1	500	34	50000	AN3534-1
		51.5		3	750			
MG-65	27.5	50	115/200	1	750	35	50000	E53805
		52		3	750			
1518 Mod. 1 & 2	27.5	105	115	1	1500	37.5	20000	—
		126		3	1800			
1518 Mod. 5	27.5	105	115	1	1500	37.5	35000	—
		126		3	1800			
MG-81	27.5	180	115/200	1	1600	61	65000	E1725
				3	1800			
32E06	27.5	150	115/200	1	2250	56	50000	E1725
		160		3	2500			
MG-70	27.5	170	115/200	1	2250	54	65000	—
				3	2500			
MG-61	27.5	170	115	1	2500	54	65000	53C6767
MG-64	27.5	170	115	3	2500	54	65000	—
32E03	27.5	160	115	1	2500	61	50000	53B6227
MG-95	27.5	150	115/200	1	2500	54	50000	E54807
		160		3	3000			
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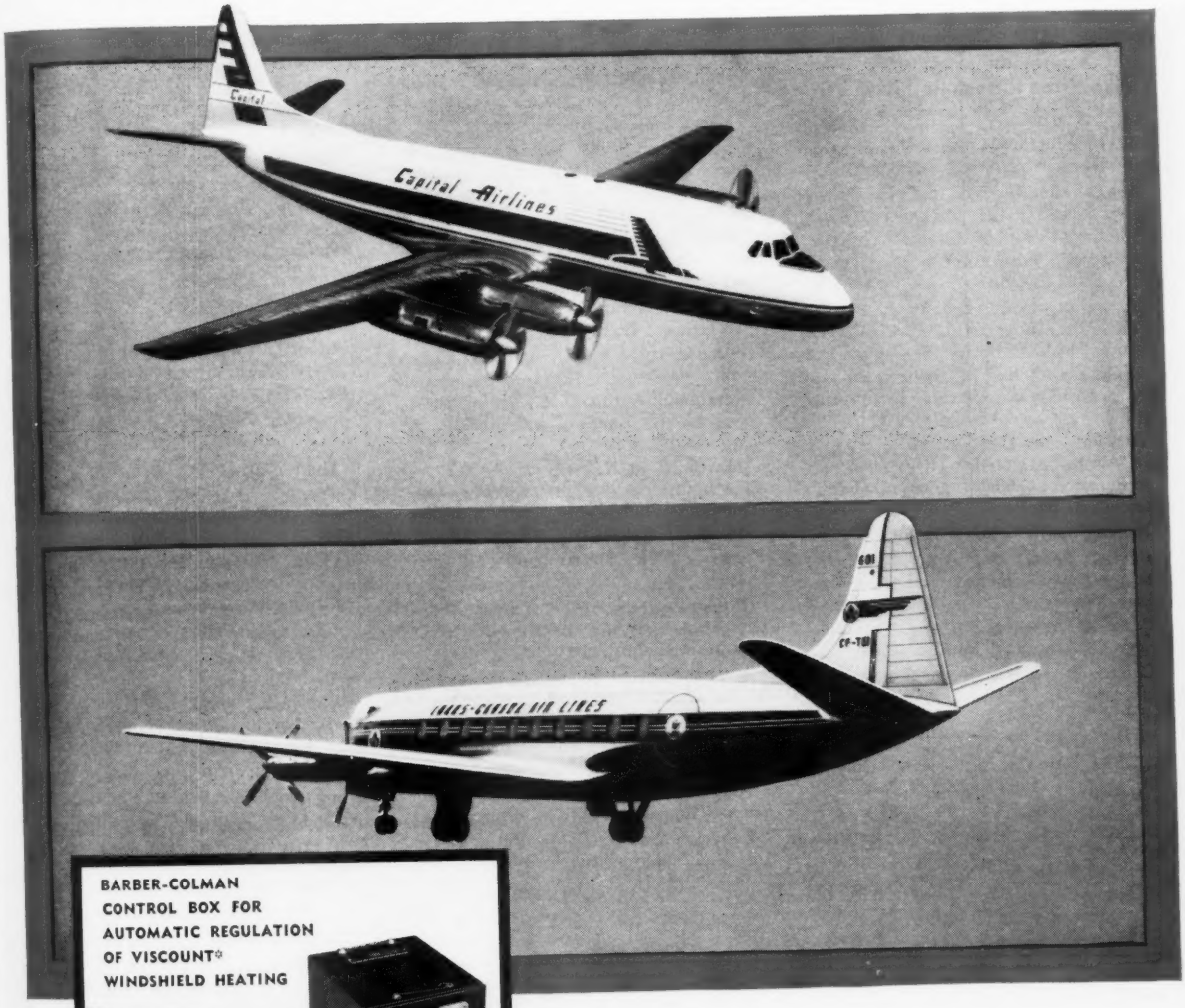

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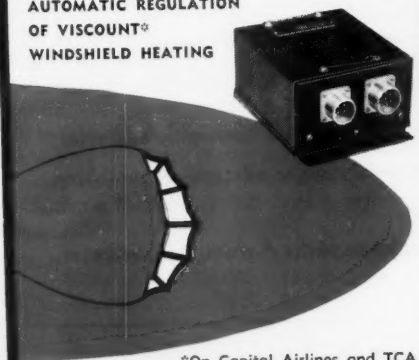

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Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

I. PERIODICALS AND REPORTS

Aerodynamics 100
Boundary Layer & Thermoaerodynamics 100
Fluid Mechanics & Aerodynamic Theory 100
Internal Flow 100
Natural Flight 102
Stability & Control 102
Wings & Airfoils 102
Aeroelasticity 104
Airplane Design 104
Control Systems 104
Landing Gear 104
Wing Group 104
Airports
Traffic Control 106
Air Transportation 106
Aviation Medicine 106
Computers 106
Education & Training 106
Electronics 106
Amplifiers 106
Antennas 106
Capacitors 106
Circuits & Components 106
Communications 106
Electronic Controls 106
Electronic Tubes 106
Magnetic Devices 106
Measurements & Testing 108
Navigation Aids 108
Networks 108
Oscillators & Signal Generators 108
Radar 109
Semiconductors 109
Transmission Lines 109
Wave Propagation 109
Flight Operating Problems
High-Speed Flight 109
Weather & Climate 109
Flight Testing 109
Fuels & Lubricants 109
Instruments 109
Accelerometers 109
Automatic Control 109
Flight Instruments 110
Flow Measuring Devices 110
Pressure Measuring Devices 110
Temperature Measuring Devices 110
Vibration Measuring Devices 110
Machine Elements 110
Bearings 110
Gears & Cams 110
Materials
Ceramics & Ceramals 110
Corrosion & Protective Coatings 110
Metals & Alloys 110
Metals & Alloys, Nonferrous 110
Nonmetallic Materials 110
Sandwich Materials 112
Testing 112
Mathematics 112
Meteorology 114
Military Aviation & Armament 114
Missiles 114
Navigation 114
Noise Reduction 114
Photography 114
Power Plants
Atomic 114
Jet & Turbine 114
Ram-Jet & Pulse-Jet 114
Reciprocating 114
Rocket 114
Production 118
Metalworking 118
Production Engineering 120
Welding 120
Propellers 120
Rotating Wing Aircraft 120
Design 120
Power Plants 120
Rotors & Blades 122
Safety 122
Space Travel 122
Structures 122
Beams & Columns 124
Cylinders & Shells 124
Elasticity & Plasticity 124
Plates 124
Wings 124
Thermodynamics
Combustion 124
Heat Transfer 124
Water-Borne Aircraft 126
Wind Tunnels & Research Facilities 126

II. BOOKS REVIEWED IN THIS ISSUE

General Theory of High Speed Aerodynamics. Edited by W. R. Sears 129
Reviewed by Clark B. Millikan, California Institute of Technology

The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. 1. Ascher H. Shapiro 130
Reviewed by Harold L. Bloom, General Electric Company

Book Notes **134**

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Aerodynamics

Jahrestagung der Gesellschaft für angewandte Mathematik und Mechanik. *ZAMM*, Aug.-Sept., 1954, p. 20. 65 refs. In German. 62-page review of the official Annual Meeting proceedings of the Society of Applied Mathematics and Mechanics held in Munich, April 20–24, 1954, with coverage on 47 papers, including 12 from the aerodynamics session.

Boundary Layer & Thermoaerodynamics

Average Skin-Friction Drag Coefficients from Tank Tests of a Parabolic Body of Revolution (NACA RM-10). Elmo J. Mottard and J. Dan Loposer. (*U.S., NACA TN 2854*, 1953). *U.S., NACA Rep. 1161*, 1954. 7 pp. Supt. of Doc., Wash. $0.15. Drag calculations from boundary-layer total-pressure measurements.

Boundary Layer Growth in Three Dimensions. L. C. Squire. *Philos. Mag.* (*7th Ser.*), Dec., 1954, p. 1272. Extension of the Goldstein-Rosenhead analysis for an impulsively started body.

Experimental Investigation of Turbulent Boundary Layers in Hypersonic Flow. R. Kenneth Lobb, Eva M. Winkler, and Jerome Persh. *J. Aero. Sci.*, Jan., 1955, p. 1. 25 refs. Experimental extension of the available skin friction data to a Mach Number of 7.7, with detailed measurements of velocity and temperature distributions in the NOL 12 by 12 cm. Hypersonic Wind Tunnel No. 4 at a Reynolds Number range of 5,000–13,000.

A Simple Laminary Boundar Layer with Secondary Flow. Henk G. Loos. *J. Aero. Sci.*, Jan., 1955, p. 35. Exact calculation of the incompressible laminar boundary layer developed on a flat plate in the simple case where the stream lines in the free flow have a parabolic shape and the free stream is rotational with a constant velocity that is directed normal to the plate as in problems of fluid motion past turbomachine blades.

Über das Spektrum bei Eigenschwingungen ebener Laminarströmungen. D. Grohne. *ZAMM*, Aug.-Sept., 1954, p. 344. 13 refs. In German. Analysis of the whole spectrum of the characteristic values and of the shape of the natural oscillations in an investigation of the stability of laminary flow.

Boundary Layer Control. Kenneth Razak. *Skyways*, Dec., 1954, p. 16. Analysis of the relative merits of a system ejecting high-energy air from a narrow slot above and ahead of a single-slotted flap to prevent turbulent-flow separation on the upper surface of the flap and again establishing a stagnation point at the flap trailing edge, with an outline of general procedures of application.

Boundary Layer Control. II. G. V. Lachmann. (*RAeS Paper*, Nov. 11, 1954.) *The Engr.*, Nov. 26, 1954, p. 751. Methods of propulsion and effects of laminarization through distributed suction on the performance of aircraft.

Investigation of a Simple Device for Preventing Separation Due to Shock and Boundary-Layer Interaction. Coleman duP. Donaldson. *U.S., NACA RM L50BO2a*, Nov. 29, 1950. 34 pp.

A Preliminary Flight Investigation of the Effects of Vortex Generators on Separation Due to Shock. Lindsay J. Lina and Wilmer H. Reed, III. *U.S., NACA RM L50JO2*, Nov. 30, 1950. 30 pp.

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Canonical Equations for Non-Linearized Steady Irrotational Conical Flow. J. H. Giese and H. Cohn. *Quart. Appl. Math.*, Jan., 1955, p. 351. 22 refs. Analysis for the case of flow about a conical body completely surrounded by a conical shock.

A Comparison of the Experimental Subsonic Pressure Distributions About Several Bodies of Revolution with Pressure Distributions Computed by Means of the Linearized Theory. Clarence W. Matthews. (*U.S., NACA TN 2519*, 1952). *U.S., NACA Rep. 1155*, 1953. 29 pp. 10 refs. Supt. of Doc., Wash. $0.30.

On the Wake and Drag of Bluff Bodies. Anatol Roshko. *J. Aero Sci.*, Feb., 1955, p. 124. 10 refs. Study of flow about a cylinder based on a modified Kirchhoff method, with an overview of fundamental problems; results of experiments in the GALCIT 20- by 20-in. low-turbulence wind tunnel.

A Method of Computing Subsonic and Transonic Plane Flows. C. S. Sinnot. *Gt. Brit., ARC CP 173* (Sept. 3, 1953), 1954. 21 pp. 13 refs. BIS, New York. $0.65. Appraisal of the basic principles and advantages of the relaxation technique.

A New Singularity of Transonic Plane Flows. A. R. Manwell. *Quart. Appl. Math.*, Jan., 1955, p. 343. 13 refs. Discussion of a singularity of the hodograph method giving infinite acceleration of the fluid and avoiding the difficulties of the limit line theory.

On Transonic Flow Past a Wave-Shaped Wall. Carl Kaplan. (*U.S., NACA TN 2748*, 1952.) *U.S., NACA Rep. 1149*, 1953. 12 pp. Supt. of Doc., Wash. $0.20. Analytical solution of a simplified nonlinear differential equation by the method of integration-in-series to prove that the assumed smooth symmetrical type of potential flow cannot exist at stream Mach Numbers beyond the critical value.

The Role of Fluid Mechanics in Aeronautical Development. G. N. Patterson and others. *Aero. Eng. Rev.*, Feb., 1955, p. 27. Evaluative review from classical hydrodynamics to the mechanics of rarefied gases as applied to aerodynamic design, covering such factors as air resistance, stability and control, and propulsion problems; research trends.

Aerodynamics of Blasts—Diffraction of Blast Around Finite Corners. J. F. Ludloff and M. B. Friedman. *J. Aero. Sci.*, Jan., 1955, p. 27. ONR-sponsored analytical study of the elliptic and hyperbolic techniques to calculate the reflection and diffraction of strong shocks around corners of arbitrary finite angle and the resulting pressure and density fields; application of the hyperbolic method to nonlinear problems.

The Quasi-Cylindrical Shock Tube. W. Chester. *Philos. Mag.* (*7th Ser.*), Dec., 1954, p. 1293. Investigation of the disturbance produced behind a shock wave of arbitrary strength travelling along a tube of varying cross section.

The Shock-Wave Cubic; Presentation of an Equation which Permits the Solution of Shock-Wave Problems without Tables. V. D. Naylor. *Aircraft Eng.*, Dec., 1954, p. 407.

A Theoretical and Experimental Study of Shock-Tube Flows. I. I. Glass and G. N. Patterson. *J. Aero. Sci.*, Feb., 1955, p. 73. 42 refs. Analysis of the basic theory, with a survey of shock-tube investigations utilizing shadowgraph, schlieren, interferometric, and other techniques.

Über die Fortpflanzung kleiner Störungen in flüssigen Medien, betrachtet als Ausbreitungsvorgang von Unstetigkeiten in den Lösungen der Bewegungsdifferentialgleichung. Johannes Nitsche. *ZAMM*, Oct.-Nov., 1954, p. 25. 15 refs. In German. Use of the method of discontinuities to determine the propagation process of a small point perturbation in two liquids adjacent along a plane with small changes of pressure and velocity; includes a detailed discussion of the distribution of the jump of pressure at the shock front.

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The Effect of Inlet Conditions on the Flow in Annular Diffusers. I. H. Johnston. *Gt. Brit., ARC CP 178* (Jan., 1953), 1954. 15 pp. BIS, New York. $0.50.

Low Speed Tests on Three Aerofoil Cascades Designed for Prescribed Surface Velocity Distributions. P. V. Crooks and W. Howard. *Australia, ARL Rep. ME. 76*, June, 1954. 33 pp. Experimental investigation of the performance of the exact Lighthill design as compared to that of a conventional compressor airfoil in cascade; use of a boundary-layer visualization technique to solve the limiting problem of laminar separation.

Numerical Solutions for Laminar-Flow Heat Transfer in Circular Tubes. W. M. Kays. *ASME Annual Meeting, New York, Nov. 28–Dec. 3, 1954, Paper 54-A-151.* 19 pp. 10 refs.

Secondary Flow in Axial-Flow Turbomachinery. L. H. Smith, Jr. *ASME Annual Meeting, New York, Nov. 28–Dec. 3, 1954, Paper 54-A-158.* 23 pp. 15 refs. Development of a method based on the conventional axial-symmetry solution to deduce the induced turning and radial velocities of the secondary flow.

Secondary Flows in Cascades of Twisted Blades. Frederic F. Ehrich. *J. Aero. Sci.*, Jan., 1955, p. 51. Use of a conceptual model similar to that of Squire and Winter to determine the perturbation resulting from a nonuniform velocity profile passing through a cascade of blades whose properties vary as a function of blade height.

Shocks in Helical Flows Through Annular Cascades of Stator Blades. Robert Wasserman and Arthur W. Goldstein. *U.S., NACA TN 3329*, Dec., 1954. 23 pp. Study by the method of character-

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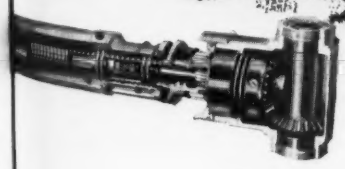

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Strömungsuntersuchungen an Schaufelgittern. I—Versuche über Drallströmungen hinter axialen Schaufelgittern. II—Ein Berechnungsverfahren zum Enturf von Schaufelgitterprofilen. Norbert Scholz. *VDI-Forschungsheft 442*, 1954. 48 pp. 23 refs. In German. Cascade flow investigations featuring: detailed measurements on axial blade rows with purely axial inflow and blade outlet angles of 16.5° and 25°; analyses of the vortex flow in the annular space behind the blade row and of the pressure distribution over the whole blade surface; and a solution of the inverse cascade theory problem under various pitch and stagger conditions.

A Study of Surge in Compressors and Jet Engines. Carl E. Pearson. *J. Aero. Sci.*, Jan., 1955, p. 10. Experimental analysis of the behavior of a theoretical surge model, with derivation of basic criteria.

On Some Solutions of the Hodograph Equation Which Yield Transonic Flows Through a Laval Nozzle. F. Edward Ehlers. *J. Aero. Sci.*, Feb., 1955, p. 107. 11 refs. Study of a group of applied solutions with the singularity at the sonic point of the form:

$$(\psi_\theta)_\psi = 0 \propto (1/s^\mu) \text{ as } s \to 0.$$

An Approximate Solution of Compressible Turbulent Boundary-Layer Development and Convective Heat Transfer in Convergent-Divergent Nozzles. Donald R. Bartz. *ASME Annual Meeting, New York, Nov. 28–Dec. 3, 1954, Paper 54-A-153.* 37 pp. 24 refs. Army Ordnance-sponsored investigation at the CIT Jet Propulsion Lab.

Water Vapor Condensation Process in Supersonic Nozzles. Appendix A—Method of Calculating Thermodynamic Properties through Condensation Zones. Peter P. Wegener. *J. Appl. Phys.*, Dec., 1954, p. 1485. 24 refs. USAF-Army Ordnance-sponsored research at the CIT Jet Propulsion Lab.; includes a review of experimental and theoretical investigations of the phenomena.

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Unusual Aerodynamics. B. S. Shenstone. *CAI Log*, Dec., 1954, p. 19. Review of the unresolved problems of low-speed natural and pseudo-natural flight.

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An Analysis of Longitudinal-Control Problems Encountered in Flight at Transonic Speeds with a Jet-Propelled Airplane. Harvey H. Brown, L. Stewart Rolls, and Lawrence A. Clousing. *U.S., NACA RM A7GO3*, Sept. 25, 1947. 56 pp.

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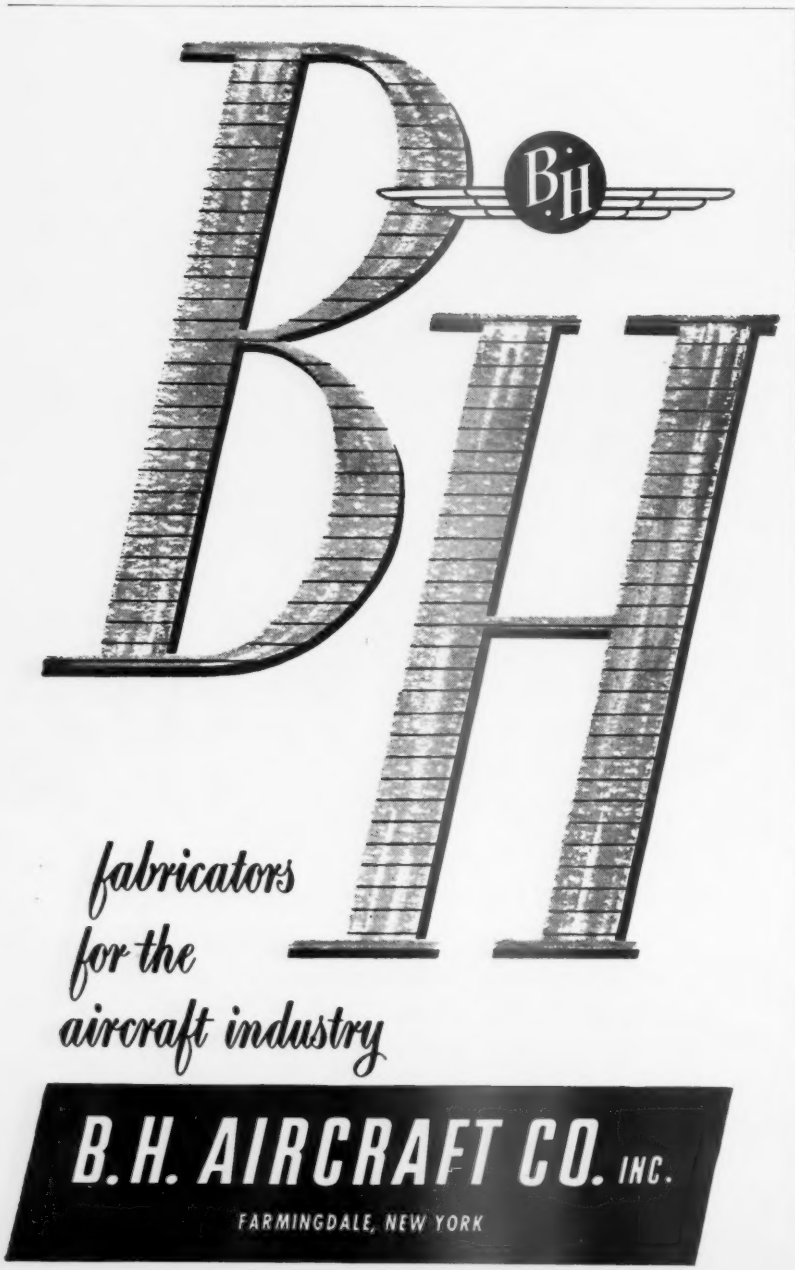

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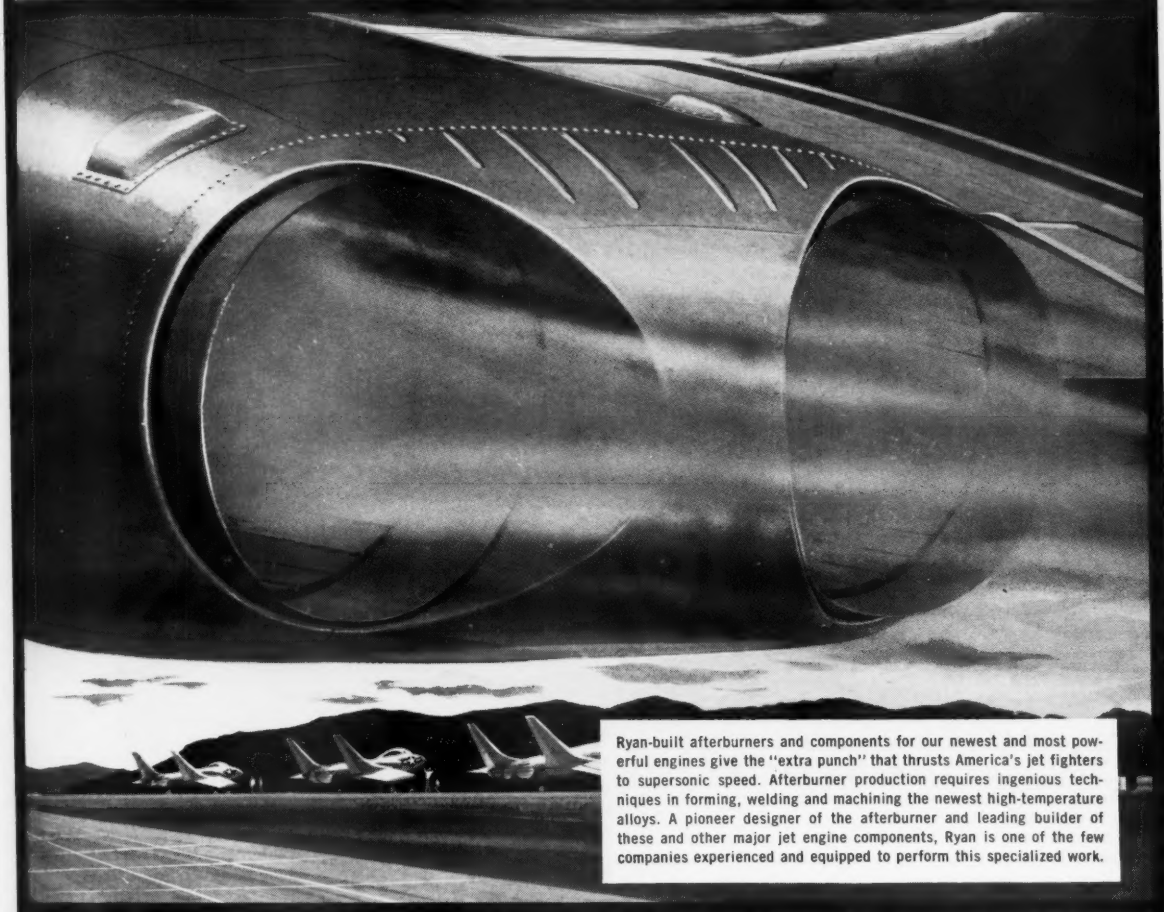

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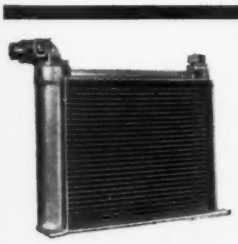

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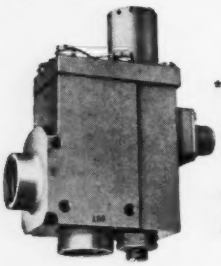

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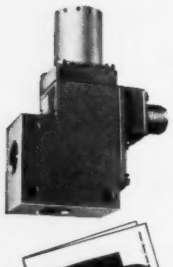

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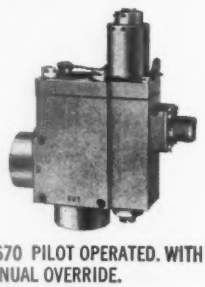

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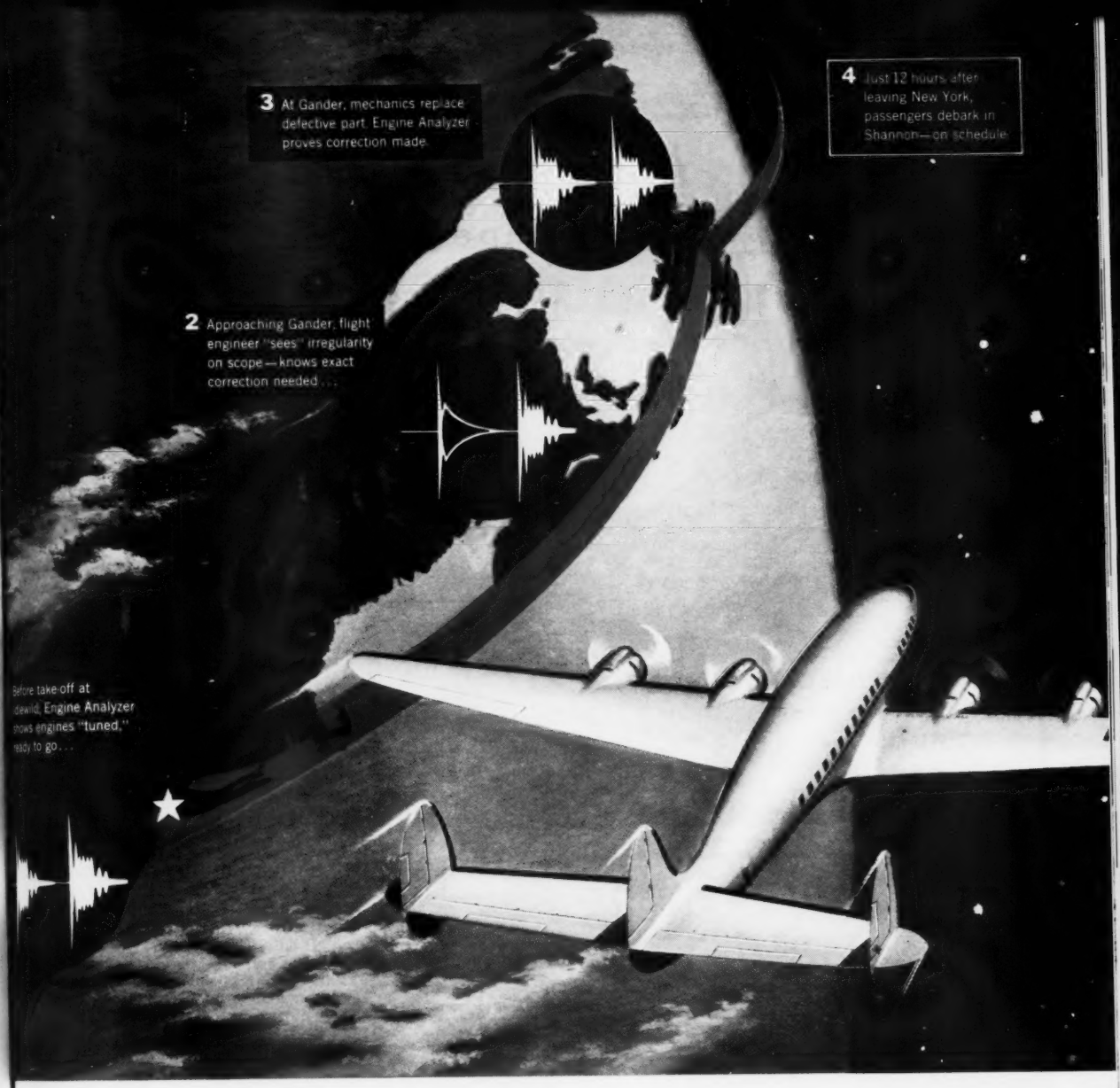
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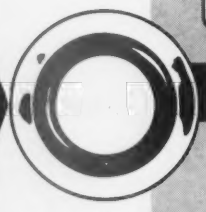

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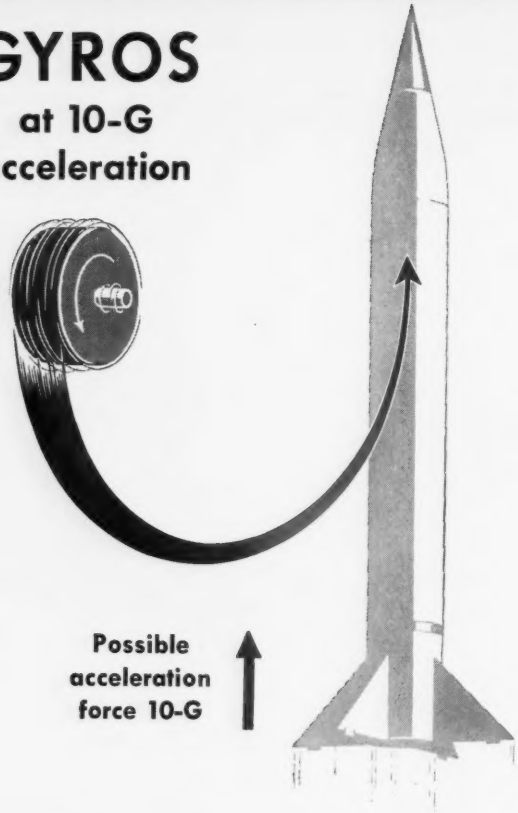

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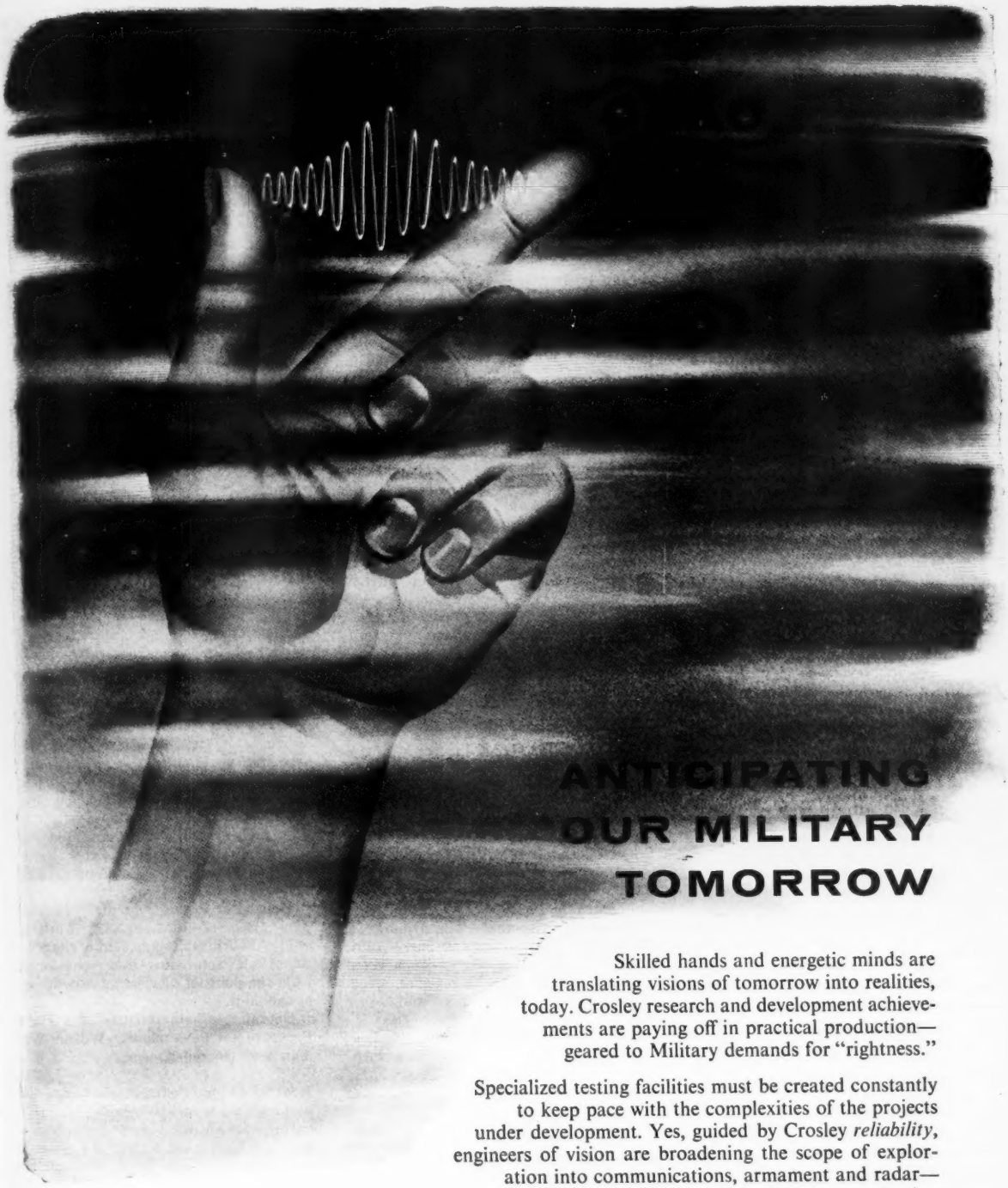

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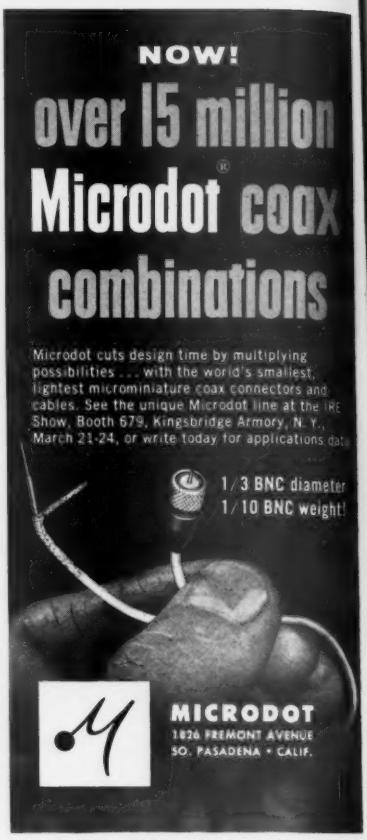
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Aeronautical Reviews — BOOKS

General Theory of High Speed Aerodynamics

W. R. Sears, Editor. (High Speed Aerodynamics and Jet Propulsion, Vol. 6.) Princeton, N.J., Princeton University Press, 1954. 758 pp., illus., diagrs., figs. $15.

This large volume presents discussions of a great variety of problems in high-speed aerodynamics by a number of different authors, each of whom has himself made important original contributions to one or more aspects of the field. This has inevitably resulted in a certain lack of logical structure for the volume considered as a whole. However this defect, if it be one, is more than compensated by the fact that the same subject is frequently considered by several of the authors; the resulting differences in approach and viewpoint are extremely illuminating and helpful to the depth of understanding of the phenomena treated in this multiple fashion. The editorial task of cross-referencing must have been a formidable one, but it has been excellently and completely accomplished. The material covered is somewhat less broad than the title would imply since, with very few exceptions, the diffusion of both shear and heat are neglected, and the flows considered are treated as adiabatic. Many of the topics are, for the first time, presented in a unified and comprehensive manner, and there is a considerable amount of new material which has not appeared before at all. Accordingly the volume should be of great interest and value to the rapidly growing group of workers, teachers, and students in the field. The extensive bibliographies at the end of each section should also prove very useful. In the following paragraphs are given brief outlines of the major problems treated by the various authors.

In a short introductory section von Kármán presents a survey of the entire field. Using a minimum of mathematics, the essential physical concepts are clearly exposed, and the types of approximations required to obtain useful results in the subsonic, transonic, supersonic, and hypersonic regimes are presented and discussed. In a sense this section furnishes the outline which is filled in and amplified in many of the subsequent, more detailed treatments of individual aspects of the field.

The second section, by Friedrichs, considers the mathematical foundations underlying the gas dynamics problem. Special emphasis is given to questions of uniqueness, existence, and continuous dependence on the given data, and of solutions of the hyperbolic differential equations used to describe situations in high-speed aerodynamics. The equations for one-dimensional, nonsteady flow of a gas are used for the detailed analysis, and the extension of the arguments to two-dimensional steady flow is briefly considered.

Sears, in the third section, develops the basic equations of small perturbation theory from the acoustic viewpoint and then translates the results into the aerodynamicist's usual steady motion notation. The Prandtl-Glauert approach to subsonic compressibility corrections is discussed in detail, and numerous comparisons between theory and experiment are presented. An introduction to slender-body theory is also given, and rotational flow perturbation theory is applied to shock-wave perturbations.

Heaslett and Lomax, in the most extensive section of the volume, apply the small perturbation theory to a wide variety of types of supersonic flow problems, each of which is considered in a separate chapter. After an introduction giving the basic integral forms of the general solutions of the Prandtl-Glauert equation, the standard results of two-dimensional, steady motion airfoil theory are developed in the second chapter, where the source concept is introduced. This concept and its extension to doublets and vortices underlie much of the authors' subsequent presentation. The treatment of steady-state, three-dimensional wing theory is based largely on the mathematical techniques of Hadamard's "finite part" integrals and of null transforms for the inversion of singular integral equations. These techniques are applied to the three fundamental formulas for the perturbation potential which correspond to the three elementary singularities mentioned just above. Although the major emphasis is on methods, a number of simple plan-form examples is worked out in detail, and the physical nature of the resulting aerodynamic forces is explicitly presented. The next four chapters deal with slender bodies of revolution in steady flow, with slender-body theory, especially in connection with the possibility it furnishes for treating complicated body shapes, with unsteady motions using Kirchhoff's retarded potential solution, and with the well-known reverse flow or reciprocity relations and their application to practical wing problems. The final chapter of the section leaves the "linearized" field and develops the similarity laws for transonic and hypersonic flows by considering higher degree terms in the perturbation quantities.

Section E, by Lighthill, deals with the nonlinear effects that are introduced when higher approximations to the small perturbation theory of steady, adiabatic flows are considered. His "mathematical technique for rendering approximate solutions to physical problems uniformly valid" underlies much of the section, although the actual treatment generally follows corresponding physical approaches rather than the mathematical formalism. Following a discussion and comparison of the various techniques that have been developed for obtaining higher approximations to subsonic flow problems, the author enters the supersonic regime with a treatment of the surface pressures on two-dimensional airfoils. The Busemann, simple wave, and shock-expansion approaches are compared with one another and with the Ackeret linearized perturbation theory. An excellent discussion is also given of the various approximation formulas that are useful for practical aerodynamic calculations. The two-dimensional theory is extended to the complete flow field, especially shock location by Friedrichs' theory, and to the effects of blunt leading edges where semi-empirical modifications to the previous theories are given. The com-

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plete flow field about figures of revolution is treated by Whitham's procedure of appropriate distortion of the linearized theory Mach waves, and formulas are developed for the location and strength of the bow and stern shocks. In connection with surface pressures, the second-order solution near the surface is made determinate by extension away from the body to satisfy conditions ahead of the bow Mach cone. Both axial and yawed flow are studied in detail. The extension of the previous ideas to truly three-dimensional problems (wings) is restricted to the nonlinear effects in conical fields.

Kuo and Sears, in Section F, apply the hodograph technique to steady, two-dimensional, subsonic and transonic flows. The hodograph equations and some particular solutions are derived and first applied in connection with the Chaplygin-Kármán-Tsien approximation. The elementary source, vortex, and Ringleb flows are then considered, and this is followed by a review of Chaplygin's classical work on free jets. Transonic flows around closed bodies and through nozzles and ducts are treated using various superposition and gas law approximation techniques. Finally, the still controversial question of the stability and existence of continuous transonic flows with shockless recompression from supersonic to subsonic speed is considered in some detail.

The two final sections are contributed by Ferri. The first, dealing with the method of characteristics, presents the classical characteristics calculation procedures for two-dimensional and axially symmetric potential flows and then goes on to discussions of rotational flow with two independent variables and of flows with three independent variables, involving either three space coordinates or one time and two space coordinates. This section ends with a presentation of linearized characteristics theory. The last section, entitled "Supersonic Flows with Shock Waves," treats a variety of problems involving shocks in transonic and supersonic flows. The first chapter, on two-dimensional and axially symmetric supersonic flows, deals with problems similar to those discussed earlier by Lighthill, although the approach is quite different. The second chapter is concerned with transonic flows and uses both characteristics and hodograph techniques. The transonic similarity laws, in a somewhat more restricted form than that presented by Heaslett and Lomax, are also employed extensively. The last chapter applies conical flow methods to a number of appropriate problems with especial emphasis on circular cones in axial and inclined flows.

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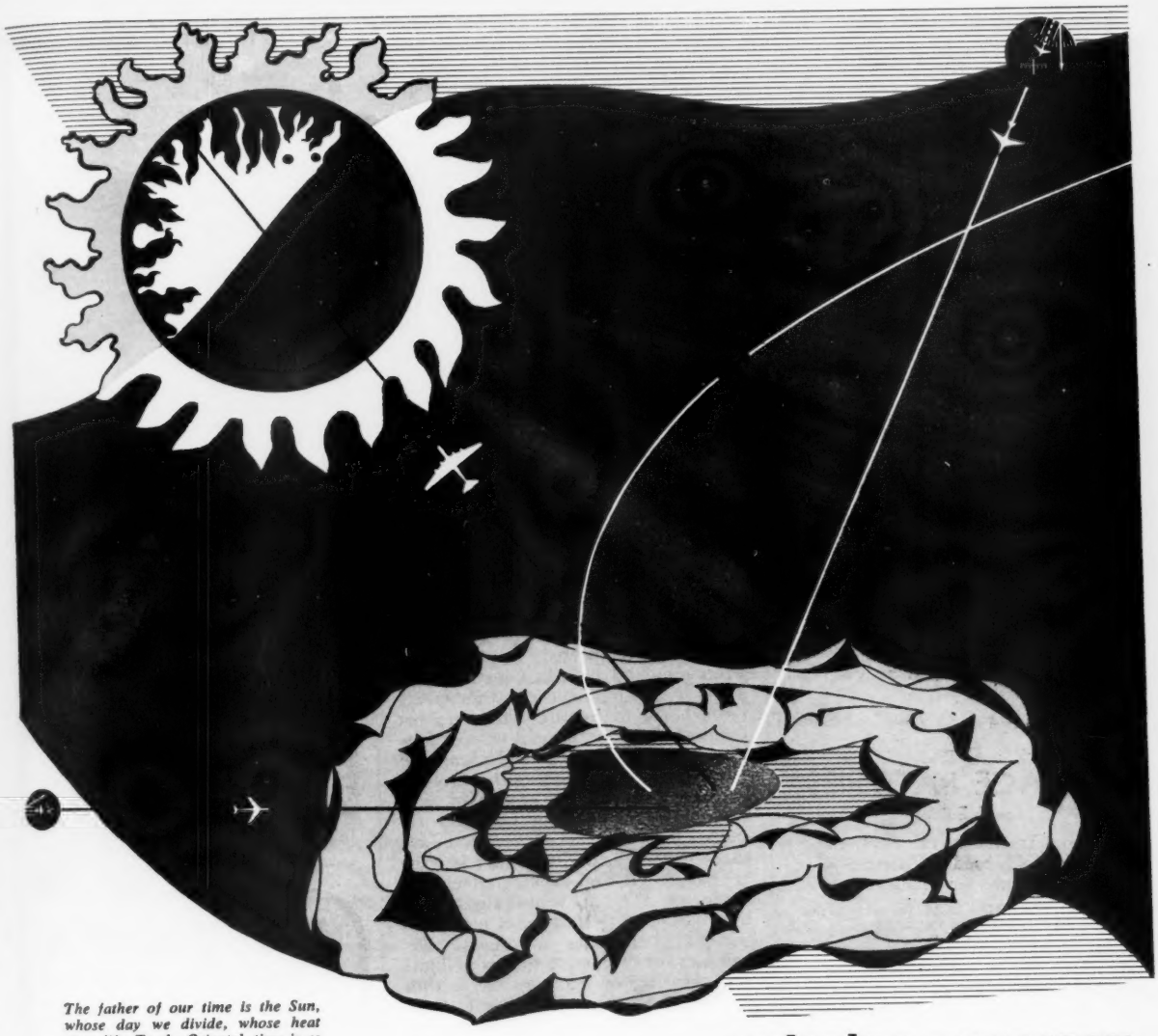
The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. 1

By Ascher H. Shapiro. New York, The Ronald Press Co., 1953. 647 pp.. illus., diagrs., figs. $16.

The author has succeeded admirably in attaining his dual objective of producing a text that will serve both as an introductory work to students of compressible fluid motion and as a reference book for advanced phases of the field. The illustrative examples, the problems at the end of each chapter, and the methodical development of fundamental fluid dynamics and thermodynamics into the complexities of compressible fluid flow will furnish the student with the necessary guidance, while the tables, references, and detailed coverage of the field will provide the practicing scientist with a valuable handbook.

The book is the first volume of a two-volume set. It is composed of five parts and an appendix. Part I presents the background information necessary to the understanding of fluid flow. The author discusses the continuum and its properties and defines "systems" and control volume by means of which the law of conservation of mass, the momentum theorem, and the theorem of moment of momentum are reduced to working form. As further background information, these chapters state the "zeroth," first, and second laws of thermodynamics and define the thermodynamic properties of the continuum. The control volume is employed to put the first and second laws into working form. Definition of the perfect gas and discussion of its behavior complete the thermodynamic review. Directing the discussion to compressible flow concepts, the author derives the expression for sound velocity. It is here that the physical differences between incompressible, subsonic, and supersonic flows are illustrated, and flow criteria are established. These include Mach Number, Kármán's rules of supersonic flow, and similarity. In addition, the limit of the continuum domain is defined. Finally, the various optical methods of flow investigation are presented and discussed. This discussion is enhanced by exceptionally clear diagrams and excellent schlieren photographs.

Part II deals with one-dimensional flow. The author opens with a discussion of the application of one-dimensional flow, both as an exact description and as an approximation to specific problems. Flow in a passage of varying cross section is then considered, and its defining equations are derived. Confining the discussion, first, to adiabatic flow, and the isentropic flow of a perfect gas, allows calculation of the resulting equations in usable engineering terms. Choking of isentropic flows is considered as well as the operation of converging and converging-diverging nozzles. Special



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Part IV concerns itself with subsonic flow. The author discusses the usefulness of approximate methods and applies simplifying assumptions to previously derived equations to develop such a method, the linearized theory. This leads in turn to the similarity laws for subsonic flow. Applications of the similarity laws are discussed, and comparisons with experiment are shown. As an additional tool in handling two-dimensional subsonic flow problems, the author presents the hodograph method. After defining the limitations of the method he derives the hodograph equations, and, introducing the tangent gas approximation, he arrives at the Kármán-Tsien formula for correcting pressures in an incompressible flow to pressures in a corresponding compressible flow. Applications of this formula are discussed, and comparisons with other pressure correction formulas and experiments are shown. Correction of incompressible flow profiles to corresponding compressible flow patterns is explained, and the required calculations are abbreviated through the introduction of complex variables. A number of applications of the above correction methods are considered as well as extensions of the Kármán-Tsien method. The author then summarizes a variety of additional methods for treating two-dimensional subsonic flows. These include the Rayleigh-Jantzen method, the Prandtl-Glauert method, the relaxation method, and the streamline curvature method. Results of these methods are given for many special cases, and illustrated comparisons are made with experimental data. In order to make the complex problems of the three-dimensional subsonic flow amenable to analysis, the author employs several simplified approaches. These techniques include a linearized theory, comparison of three-dimensional flows to solvable two-dimensional flows, and exact analysis of certain mathematically simple bodies. The favorable influence of the three-dimensional relief effect is demonstrated by experimental results that serve as checks on the above approaches. Results are shown for both bodies and wings, and Diederich's semi-empirical generalized wing-lift formula is given.

Part V deals with supersonic flow. As in subsonic flow treatment, the equation of motion is linearized by the author, who defines the restrictions inferred by such linearization and obtains its general solution. The flows described by the general solution are interpreted from both the mathematical and the physical standpoints. Based on these interpretations and the linearized Euler equation, the author explains the construction of a two-dimensional flow pattern. This is accomplished through the use of flow turning by means of four basic types of Mach waves. Application of the wave solution to the linearized equation of motion is demonstrated in solving the flow past a wave-shaped wall and the flow over various supersonic airfoils of infinite span. For these airfoils, pressure distribution, lift, drag, moment, and center of pressure equations are determined. The theoretical results are supplemented by experimental data shown for several airfoil profiles. Further extension of the wave solution, and explanation of the wave processes allow the author to analyze the problems of overexpanded and underexpanded jets, and the supersonic flat plate biplane. Following the linearized approximations for two-dimensional supersonic flow, the author discusses the simplified case of Prandtl-Meyer flow, and obtains the exact solution for simple waves. For this case, there are given a summary of calculation rules and a table of useful functions. In addition, there are shown hodograph diagrams of several simple wave flows. Applying the hodograph diagram, flows combining two sets of waves are examined from a physical standpoint. The use of hodograph characteristics for such a flow is explained and clearly illustrated. Analytic foundations of the above method of characteristics are derived, and its limitations established. Further discussion on the method of characteristics includes an explanation of the "field" and "lattice-point" procedures, a summary of the flow construction "tools" called unit processes, analysis of graphic and numerical characteristics net constructions, and illustrations of the applications of the method. Such applications include the thin airfoil in supersonic flow, the underexpanded nozzle, the supersonic wind tunnel, the turbine blade, the compressor cascade, and the two-dimensional supersonic inlet. A comprehensive section on the design of supersonic wind tunnel nozzles is accompanied by several pertinent illustrations. Finally, the method of characteristics is extended to a nonviscous flow with rotation. Turning to oblique shocks, the author introduces this phenomenon through transformation from normal shocks. After distinguishing between Mach waves and oblique shocks, the author derives the equations describing these shocks. Among the more useful relationships thus obtained are the Rankine-Hugoniot equations, and the Prandtl velocity relation. Working formulas, tables, and charts are presented for solutions of oblique shock problems. Rules governing the geometry of the flow in the region of an oblique shock are given as well as the reasoning that proves the impossibility of expansion shocks. Graphic representation of oblique shock relations is shown by two useful constructions, the hodograph shock polar and the pressure-deflection shock polar. The strong and weak shock solutions obtained from these constructions are discussed, as well as the cases of detached shocks and very weak shocks. Next, the author analyzes the reflection and interaction of oblique shocks in an excellently illustrated section. Applicability of the previously derived equations to curved shocks is then discussed, followed by series expansions of the solutions for waves and for oblique shocks. Illustrations of two-dimensional flows containing shocks are discussed on the basis of characteristics theory and oblique shock theory. These flows include the overexpanded jet, the turbine nozzle jet, and the oblique shock diffuser. On the same basis, the author discusses the aerodynamic characteristics of two-dimensional profiles and derives the second-order equations of these characteristics for several profiles. After discussing typical supersonic airfoil profiles, the author presents some results of experimental measurements on airfoil profiles and makes comparisons with various solutions obtained previously. The airfoil profile discussion continues with an analysis of downwash, wake waves, and the Busemann supersonic biplane. A short introduction to boundary layers is given, and several cases of boundary-layer shock interaction are explained. These include oblique shock impinging on a flat plate, normal shock in a duct, and shock propagated at a bend.

Appendix A outlines the mathematical theory underlying the method of characteristics. Appendix B contains tables of compressible flow functions, as follows: Properties of the Standard Atmosphere (NACA); Isentropic Flow; Normal Shock; Frictional Adiabatic Constant-Area Flow (Fanno Line); Frictionless, Constant-Area Flow with Stagnation Temperature Change (Rayleigh Line) for Two-Dimensional, Isentropic Supersonic Flow; and Coefficients for Second-Order Theory of Two-Dimensional Supersonic Flow.

The book is a product of a task well done. The reviewer feels that the omission of sections on the measurement of physical quantities in a compressible flow and on an introduction to the kinetic theory of gases are only minor criticisms in view of the magnitude of the scope of the work. Should the concluding volume prove to be as detailed and clear as the first, Mr. Shapiro will find himself the author of one of the first "encyclopedias" of compressible fluid flow.

HAROLD L. BLOOM
General Electric Company

Book Notes

AIRPLANES

Standard Method for the Estimation of Direct Operating Costs of Aircraft. Issue No. 2. London, The Society of British Aircraft Constructors, January, 1953. 23 pp., figs.

The object of this method is to aid a potential operator to assess the economic suitability of an airplane for his operations and to provide a ready means for comparing the operating economics of competitive aircraft in a standard set of conditions. In this second edition, provisional values are given for turbojet and turboprop aircraft. Operating costs are divided into two categories:

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direct and indirect. This method deals only with the direct operating costs taken to be the sum of all the costs of flying and maintaining an airplane together with appropriate allowances on insurance, obsolescence, and landing fees. The calculations for making the estimate are summarized by formulas without symbols, and their derivation is shown in a separate section. Five pages are devoted to a worked example, and the booklet concludes with an appendix giving an analysis of standard crew costs, a table of landing fees, and an outline for weight analysis.

Airplanes of the World, From Pusher to Jet, 1490 to 1954. Douglas Rolfe and Alexis Dawydoff. New York, Simon and Schuster, 1954. 319 pp., illus. $2.95.

A record of the development of airplane configuration and structure as shown by over a thousand drawings of aircraft from the earliest attempts to the designs of the present. Accompanying each drawing is a caption giving notable data about the aircraft. The book is divided into chronological sections, each of which is prefaced by an historical summary.

CONTROL SYSTEMS

Feedback Control Systems. Gilbert Howard Fett. New York, Prentice-Hall, Inc., 1954. 361 pp., figs. $9.95.

This book is intended to serve the needs of the advanced engineering student and the practicing engineer in industry who wish to obtain a basic understanding of feedback control systems and the tools and techniques required to solve the newer problems in this field. The inter-relation of the power and electronics aspects of electrical engineering and of mechanics and mathematics are emphasized, and some of the illustrations require the use of material from all of these areas. Problems are listed at the ends of chapters.

Contents: (1) Introduction to Control Devices; (2) Components of Feedback Control System; (3) Steady State and Transient Solutions of Feedback Control System Differential Equations; (4) Nyquist Criterion for Stability; (5) Stability Diagram; (6) Analysis and Synthesis of Complex Control Systems; (7) Nonlinear Feedback Control System Analysis.

FUELS & LUBRICANTS

Manufacture and Application of Lubrication Greases. C. J. Boner. New York, Reinhold Publishing Corp., 1954. 977 pp., illus., diagrs., figs. $18.50.

The book describes the structure and theory of lubricating greases and devotes full chapters to all raw materials, processes, and manufacturing equipment. Lubricants containing specific thickeners and additives, including such new developments as lithium soaps, complex soaps, and non-soap gelling agents, receive detailed attention. Special emphasis is placed on the effects of each ingredient or treatment upon the characteristics of the final product, and the methods of evaluating these characteristics by either chemical or physical means. The author is Chief Research Chemist, Battenfeld Grease and Oil Corporation.

Contents: Introduction. Structure and Theory. Additives Other Than Structure Modifiers. Raw Materials. Manufacturing Processes. Equipment for Lubricating Grease Manufacture. Aluminum Base Lubricating Greases. Barium Base Lubricating Greases. Calcium Base Lubricating Greases. Lithium Base Lubricating Greases. Sodium Base Lubricating Greases. Lead Soap Lubricating Greases. Strontium Base Lubricating Greases. Miscellaneous Metal Soaps as Components of Lubricating Greases. Mixed Base Lubricating Greases. Complex Soap Lubricating Greases. Non-Soap Thickeners for Lubricating Fluids. Fillers in Lubricating Greases and Solid Lubricants. Residua and Petrolatums as Lubricants. Analysis of Lubricating Greases. Tests of Lubricating Greases and Their Significance. Application of Lubricating Greases. Trends in Lubricating Greases. Index.

GRAPHS & CHARTS

Handbook of Graphic Presentation. Calvin F. Schmid. New York, The Ronald Press Company, 1954. 316 pp., illus., diagrs., figs. $6.00.

A working manual for those concerned with the clear presentation and interpretation of statistical data in graphic form.

MATERIALS

Deterioration of Materials: Causes and Preventive Techniques. A Collaboration under the Joint Auspices of the Services Technical Committee of the Department of Defense and the Prevention of Deterioration Center, Division of Chemistry and Chemical Technology, National Academy of Sciences—National Research Council. Edited by Glenn A. Greathouse and Carl J. Wessel. New York, Reinhold Publishing Corp., 1954. 835 pp., illus., diagrs., figs. $12.

This volume represents the cooperative effort and accumulated knowledge of numerous specialists in many interrelated fields collected over the past 14 years. Twenty-four of these experts have contributed to this work, which describes and analyzes the causes of deterioration in materials and presents proven techniques for preventing or retarding such deterioration. It is intended to be a reference work and a source book on prevention techniques, and it attempts to extract general principles from the mass of data and to present them as an introduction to the various aspects of deterioration problems. Profusely illustrated and thoroughly indexed, the volume covers in detail the climatic, physical, chemical, and biological agents of deterioration; materials such as metals, wood, paper, textiles, cordage, leather, plastics and rubber, paints, varnishes, lacquers and enamels; electrical, electronic, and other equipment; dehumidification; storage and packaging; and toxicologic aspects of preserva-

(*Continued on page 142*)

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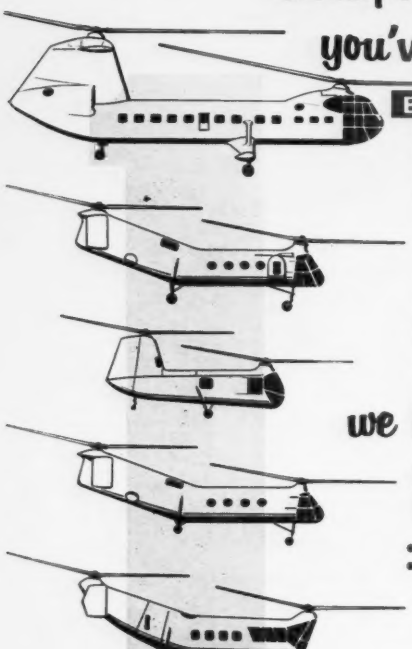

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1927—Covering wing of early Boeing plane, Seattle plant

1955—B-47 Stratojet assembly, Boeing Wichita Division

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Books

(*Continued from page 136*)

tives used. Appendixes are provided on climatic systems and on specifications useful for those doing business with Government agencies.

Report on the Elevated-Temperature Properties of Selected Super-Strength Alloys; Data Compiled by and Issued under the Auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals. Prepared for the Panel by Ward F. Simmons and Howard C. Cross. (Special Technical Publication No. 160.) Philadelphia, American Society for Testing Materials, 1954. 207 pp., diagrs. $4.75.

This report is primarily a graphic summary of the elevated-temperature strength data for 13 selected super-strength alloys. Included are summary curves for tensile strength; 0.2 per cent offset yield strength; per cent elongation and reduction of area; stresses for rupture in 100, 1,000, 10,000, and 100,000 hours when available; and stresses for creep rates of 0.0001 and 0.000001 per cent per hour (1 per cent in 10,000 and 100,000 hours). Also included are brief descriptions of each alloy giving chemical composition and recommended heat treatments and processing. The original data sheets containing the primary data from which the summary curves were prepared are also given. These data sheets also contain the chemical composition, processing data, heat treatment, and other pertinent information for the specific heats for which data are given. The Appendix contains some very-short-time rupture data for several of the alloys, and a compilation of chemical compositions for approximately 100 super-strength alloys.

Metallurgy of the Non-Ferrous Metals. W. H. Dennis. London, Sir Isaac Pitman & Sons, Ltd.; New York, Pitman Publishing Corp., 1954. 647 pp., illus., diagrs., figs. $12.50.

A handbook dealing with the extraction and refining of nonferrous metals for students, metallurgists, engineers, chemists, and executives. The text deals with the metals roughly in order of their industrial production, giving first, the source; second, the operations concerned in the extraction from the particular mineral or minerals; third, the refining of the crude metal; and, in the case of the major metals, their properties, alloys, and uses.

MECHANICS

Engineering Dynamics, Vol. 1, Theory of Elasticity: Analytical and Experimental Methods. C. B. Biezeno and R. Grammel. Translated from the Original German by M. L. Meyer. London, Blackie & Son Limited, 1954. 307 pp., illus., diagrs., figs. 50*s*.

This volume is a translation of the German edition of 1939 and has been revised to conform with the second (1953) edition. The major portion of the book deals with stress calculations of elements of machinery. It opens with a summary of elastomechanics and develops in a general form the statics of stresses and the geometry of displacements. The author then discusses the relationships between stress and strain (elastic behavior) and establishes the differential equations of elastomechanics, especially those of "normal" equilibrium. He then develops the fundamental equations of the so-called "neutral" equilibrium. In Part 2, General Theorems of Elastomechanics, are grouped all the variational theorems that permit the determination of displacements and stresses by the principle of minimum energy, the energy equation, and the Hamiltonian principle; then the energy and reciprocal theorems of Clapeyron, Betti, Castigliano, and Maxwell, a discussion of Maxwell's influence coefficients, and Saint-Venant's principle; and finally the equations determining those states of stress and strain which are functions of two coordinates only. In Part 3 are described important analytic and experimental methods of solution which are referred to in the later volumes. First is a catalog of integrals of the Laplacian and biharmonic equations and a short summary of biharmonic analysis. These are followed by the so-called direct numerical methods of solving problems of boundary values and eigenvalues and some special methods based on the division of a continuous solid into a discontinuous system. Concluding is a synopsis of highly perfected techniques of experimental stress analysis; mechanical stress determination, soap film analogy, electrical analogy, and the optical method.

PHOTOGRAPHY

Photographic Measurements; Problems and Solutions. Gomer T. McNeil. New York, Pitman Publishing Corp., 1954. 254 pp., illus., diagrs., figs. $5.00.

The primary aim of this handbook is to make available, for ready reference, 101 basic problems and solutions involving the general application of measurements in photography. The problems and solutions are presented for the combined use of the photographer, photographic interpreter, and photogrammetrist. In its first form, this book was prepared under the sponsorship of the U.S. Navy Bureau of Aeronautics, Photographic Interpretation Center.

ROTATING WING AIRCRAFT

The Helicopter and How It Flies. John Fay. London, Sir Isaac Pitman & Sons, Ltd.; New York, Pitman Publishing Corp., 1954. 105 pp., illus., diagrs., figs. $2.50.

A presentation of the fundamental features of rotary-wing flight for pilots, technicians, and laymen. The subject is divided into eight principal topics: the definition of and types of helicopter; the theory and control of the helicopter in vertical powered flight; the theory and operation of the helicopter in powered translational flight; movement about the normal axis and the effect of the tail rotor; special characteristics of the main rotor; the gyroplane and some of its lessons for the helicopter; stability; and general considerations on vibration, tracking, counterweights, and center of gravity. The volume concludes with a glossary and subject index. The text is illustrated with more than one hundred line drawings, and the author has avoided the use of mathematical formulas.

STRUCTURES

1953 References on Fatigue. (Special Technical Publication No. 9-E.) Philadelphia, American Society for Testing Materials, 1954. 34 pp. $1.85.

This is a list of approximately 175 references to articles published in 1953 dealing with fatigue of structures and materials, following the plan used in previous annual lists from 1950 through 1952. References are generally so arranged that sheets can be cut apart for filing according to any desired plan. Brief abstracts have been included when these were readily available.

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